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MATURITY

PRECOOLING

TRANSIT REFRIGERATION

OF CALIFORNIA PLUMS DURING THE

1941 SEASON

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(A cooperative investigation by the Bureau of Plant Industry, U. S. Department of Agriculture; the Division of Pomology, California Agricultural Experiment Station; and the California Tree Fruit Agreement.)

By

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## INTRODUCTION

Some shipments of California plums have been discounted in past seasons because they have arrived either too ripe or too green for the Eastern markets. It has not been known whether the fault was in picking the fruit at the wrong stage of maturity or whether the refrigeration that the fruit received was inadequate or more than was actually needed. The plums industry, acting through the California Tree Fruit Agreement, requested the California Agricultural Experimental Station and the U. S. Department of Agriculture to begin an investigation in 1941 of the various factors that might be involved in the successful shipment of the important plum varieties. The facilities of the Agricultural Experimental Station at Davis and those of the U. S. Department of Agriculture at Fresno and New York City were made available for the work. Personnel from these research organizations were assigned to the investigation and met with committees from the plum industry to outline the work that needed to be done. The California Tree Fruit Agreement provided personnel and funds to assist in this work.

## OUTLINE OF TESTS

It was agreed that the main objects of the work were (1) to find out how much plums of different maturities ripen under actual shipping conditions, (2) what the market limitations are with respect to color and firmness, (3) the comparative flavor of different maturities after being ripened, and (4) how much refrigeration is needed to ship fruit of the several maturities. Plums representing those that were being packed commercially were segregated into crates of uniform maturity. They were then color photographed and upon arrival were rephotographed under standardized conditions to eliminate avoidable differences in color reproductions. Inspection methods at shipping point and on the market were likewise uniform. Notes taken on the fruit included its firmness, ground color, the amount and intensity of over-color, and general appearance when packed. A similar inspection was made upon arrival and again when the fruit was ripe. In many shipments, as an additional possible maturity index, the soluble solids of plums of different sizes and maturities was determined with a refractometer at the time they were packed and again when the fruit was ripe. The flavor of the ripened fruit was systematically scored by the workers in New York to determine whether it was poor, acceptable, good or superior in quality. Defects such as the amount of decay, etc. were likewise noted. From the color photographs that were taken and the inspection records that were made, it was possible to tell just how much color developed in transit and how much the fruit softened. By consulting fruit wholesalers and retailers it was likewise possible to determine whether it was of a desirable maturity or color for the trade.

The temperature that the fruit was subjected to from the time it was loaded into the car or precooling room until it was unloaded at destination was recorded by thermometers packed with the fruit. The temperature curves thus obtained were averaged with a planimeter to give the average transit temperature of the fruit. Temperatures were also taken throughout the carload during precooling by means of electric resistance thermometers which could be read from outside the car. The test packages of fruit were subjected to a wide range of transit temperatures by loading some of them in the cool part of the load in the bottom

layer next to the bunker and others in a warm location in the top layer near the doorway. In some cases the fruit was shipped in pairs of cars, one receiving more refrigeration than the other.

Twenty tests were made during the course of the work (table 1). These consisted of 8 shipments of Beauty plums, beginning May 29 in Fresno County and extending to June 20 in Placer County, 7 shipments of the Santa Rosa variety from Kern, Fresno and Placer Counties, during the period June 10 to July 1, and 5 shipments of Duarte plums from Placer and San Joaquin Counties. Other varieties included in the tests, but in smaller amounts, were Formosa, Tragedy, Grand Duke, President and other late varieties. Some of these shipments were lost because of a train wreck.

To simplify tabulating the results, the maturity of the fruit was designated by numbers. Fruit classified as maturity 2 would not meet the minimum maturity requirements for that variety. Maturity 3 barely met these requirements and in some cases it included fruit lacking the required over-color or flesh color but possessing equivalent maturity. Maturity 4 was one stage above the minimum requirements, and maturity 5 was two stages above the minimum. Samples of fruit from all of the test shipments were held at Fresno and Davis under refrigeration similar to that obtained in top layers of well refrigerated cars. Changes in color and firmness that took place during a 10-day period and the quality when ripe were recorded to supplement the shipping test records.

## RESULTS

### Condition of plums on arrival and their flavor when ripe as related to their maturity and refrigeration.

### BEAUTY PLUMS

#### Maturity Classification.

The present minimum standard of maturity for Beauty plums as enforced by the California Tree Fruit Agreement requires a skin color of full yellowish green or a trace of red. Fruit lacking in the required color may, however, be certified as having "equivalent maturity" if the flesh "gives" under slight pressure and the ground color has changed from the waxy green of immature fruit.

Maturity 3 represented Beauty plums possessing the minimum requirements. Most test lots were of a yellowish green to straw ground color or had a trace of pink at the tip. (In some shipments this grade lacked the required color and was passed on equivalent maturity.)

Maturity 4 had 2 to 10 percent pink to red color, hard to firm flesh, and no softening at the tip.

Maturity 5 represented fruit of 15 to 25 percent pink to red color without noticeable softening at the tip.

Flavor Comparisons.

Flavor was scored by using numbers; with 1 to 24 representing poor flavor, 25 to 49 fair, 50 to 74 good, and 75 to 100 excellent. The average of scores assigned by several people who tasted the fruit and the mean of the averages for each maturity of Beauty plums shipped in the bottom and top layers of the cars is shown in table 2. The average flavor index of maturities 3, 4, and 5, shipped in the bottom layers or cold part of the car was 28, 45, and 50, respectively, plums of maturities 4 and 5 having much better flavor than those of maturity 3. Very similar averages were obtained in judging the quality of the different samples held at Davis and at Fresno. Plums of maturity 5 were usually definitely good, sweet and juicy. Those of maturity 4 were in some instances equal to those of maturity 5 but the quality was more variable and the general average somewhat lower. Fruit harvested at stage 3, representing minimum passable maturity, was definitely inferior. In most instances the rating was "poor". At New York maturity 3 ripened with better flavor when shipped in the top layer or warm part of the car where average transit temperatures ranged from 41° to 50°F., whereas, in most instances maturities 4 and 5 were best when shipped in the bottom layer or cold part of the car with transit temperatures ranging from 35° to 44°. Whether or not low temperatures in transit actually injure Beauty plums of minimum maturity and prevent maximum development of flavor will have to be determined by other experiments.

The relatively low transit temperatures prevailing in top layers of cars equipped with air circulating devices and the carrying of advanced maturities in the top layers of these cars will be discussed later.

Comparison of sizes.

Good flavor in plums is apparently associated with large size as well as with advanced maturity at time of picking. The percentage of soluble solids (mostly sugar) when picked and the flavor when ripe are shown in table 3. The average of 7 lots shows Beauty plums of 4 x 4 size to have 1.3 percent more soluble solids than size 5 x 5 and although only two lots (1, 4 x 5 and 1, 4 x 4) were given a flavor rating of good by the tasting jury there was only one poor lot of size 4 x 4, whereas four were poor of size 5 x 5. The test lots presented in table 3 contained samples of all three sizes. From these data alone, high quality (sugar and flavor) appears to be associated more with large size than with advanced maturity within a size but many other tests with fruit alike in size but differing in maturity have shown that the more mature fruit ripens with best flavor. Concerning the effect of time of harvest on quality, the data in table 3 indicate an increase in quality as the season advances for fruit of the same size and maturity, particularly the fruit from Kern County which was taken from one orchard for all shipping tests during the season.

Time to ripen.

A record was kept of the time required to ripen the fruit and the decay which occurred after arrival at the market. Beauty plums greener than maturity 3 usually required a week to 10 days to ripen and

the most immature lots ripened unevenly and with a great deal of shriveling. The ripest fruit shipped, maturity 5 (with 15 to 25 percent color), ripened in one or two days after arrival at the market. Maturities 3 and 4, comprising fruit with straw-color tip to 10 percent pink required 2 to 3 days to ripen when shipped in the top layer of the car and 2 to 4 days when shipped in the bottom layer or relatively cold part of the car.

Decay.

Practically no decay developed in transit in the test crates. Immature fruit developed 0 to 3 percent decay during the long period required for ripening. Decay amounting to 1 to 5 percent occurred in only 3 of the 12 lots of maturity 3 and no decay occurred in the other 9 lots. Nineteen lots of maturities 4 and 5 were shipped, 6 of which showed decay ranging from 1 to 9 percent. Whenever decay occurred it was usually slightly more prevalent in the crates that had been shipped in the top layers of the car. Blue mold, following mechanical damage was most common although brown rot and Rhizopus rot was also found in some instances.

Color and firmness changes in transit.

The influence of precooling and of transit temperatures as determined by changes in color and condition that took place enroute, together with the general market condition of the fruit, is shown in table 4 for Beauty plums.

Average temperature differences between the top and bottom of the load in test cars during the transit period was approximately 6°F.; fruit temperatures in the top layers of the load ranging from 41° to 50°; those in the bottom layers from 35° to 44°.

Test crates of fruit from different growers even though classed as being of the same maturity frequently showed considerable variation in color. In general, however, the following changes occurred in Beauty plums.

Fruit of maturity 3, greenish yellow to straw occasionally with a trace of pink on the tip, arrived with most samples showing only a trace of pink color when carried in the bottom of the load. (Ten percent of color was recorded in one sample.) This fruit arrived still having a green appearance and with hard or firm flesh. Comparable crates of the same fruit shipped in the top of the load showed in most instances one-third pink to red color.

Fruit of maturity 4 with 2 to 10 percent of the surface pink to red when shipped in the bottom layer arrived with most samples showing 5 to 15 percent color; fruit of this maturity shipped in the top layer had 75 to 85 percent color on arrival. Only in one lot did the fruit from the bottom of the load show more color or softening than was desired. All samples carried in the top of the load, however, were on the ripe side.

Fruit of maturity 5, picked with 15 to 25 percent of the surface

pink or red color. had in most instances on arrival 25 to 30 percent color in the bottom crates and 60 to 100 percent in the top crates. This fruit carried well in the bottom crates but generally ripened too much when shipped in the top of the load. Usually ripening in transit resulted only in the development of color and not in excessive softening.

Comparable lots of the same Beauty plums that were shipped were held for a ten-day period in storage at Davis or Fresno at a temperature of 42° to 45°F. At the end of the holding period the amount of coloring which had developed was as follows:

| | After 10 days at 42°F. | |
|---|---|---|
| Maturity | Color | Firmness |
| #3 yel. gr. to straw | 2 to 30% pink | Mostly firm |
| #4 yel. gr. to straw with pink tip | 15 to 50% pink to lt. red (one sample 95% color) | Firm to soft; mostly fairly firm |
| #5 15 to 25% color | 50 to 85% pink to red | Fairly firm to soft; mostly fairly firm |

The results of these holding tests agree with those secured from the test shipments. Detailed data are presented in table 5.

Market acceptance.

Information obtained from wholesale buyers indicated that the color of Beauty plums preferred by them is considerably more than the amount required to pass inspection at shipping point. Plums of this variety showing from 10 to 50 percent pink to red color without soft tips were regarded as being most desirable. Obviously if fruit of maturity 3 (having only minimum maturity requirements for passing inspection) is to meet this preference it will have to ripen in transit. The results secured from the shipping tests show that such fruit carried in the lower layer of the load where temperatures as low as 35° existed arrived hard and green, or at least definitely on the green side. Under higher temperatures (41° to 50°F.) fruit of this maturity arrived with acceptable color.

Fruit of maturity 4 picked with a red tip and loaded in the bottom layer of the car likewise generally arrived with a desired amount of color. Only one lot arrived slightly over colored. All samples carried in the top of loads, however, arrived showing too much color.

Fruit of maturity 5 (15 to 25 percent color with firm tips) carried well in the bottom layer but generally arrived "ripe" when shipped in the top layer, that is, with more color than was desired.

The result of one season's work is not enough to warrant conclusions but the evidence points strongly to the desirability of placing yellowish green and straw tip Beauty plums (maturity 3) in the top layers of the car and "pink tips" and riper fruit (maturities 4 and 5) in the bottom layers or relatively cold part of the load.

Beauty plums of maturity 3 and 4 (straw color tip to 10 percent pink) arrived in firm enough condition to withstand normal handling but fruit of maturity 5 (15 to 25 percent color), although not soft upon arrival, was too far advanced in ripeness to be handled without special care and promptness.

Information obtained from the retail trade shows that there is no objection to high-colored fruit provided it is not soft. Uniform ripeness throughout the crate was preferred. When green fruit is wanted by a retailer, he apparently prefers a crate containing all green fruit to one containing a mixture of green and ripe fruit.

## SANTA ROSA PLUMS

### Maturity classification.

Santa Rosa plums of maturity 3 were those showing $\frac{1}{4}$ of the surface distinctly red or $\frac{1}{2}$ pink to red color. This corresponded to the minimum maturity acceptable for eastern shipment in 1941. Some plums with less color were passed on "equivalent maturity" usually because ground color and flesh indicated a mature condition.

Maturity 4 was used to describe plums showing $\frac{1}{2}$ full color.

Maturity 5 was nearly full colored fruit.

### Flavor comparisons.

When the Santa Rosa plums were ripened at New York considerable differences in quality were discernible between maturities (table 6). Fruit of maturity 5, nearly full colored when shipped, was by far the best, being rated excellent. Next in quality was the $\frac{1}{2}$ colored fruit, or maturity 4, and third was the minimum maturity, but even this was classed as good. Similar differences between maturities were noted in the holding tests. Fruit passed on equivalent maturity and shipped in the top layer was as good as that which met the color requirements, but there was some indication that the flavor of the former was impaired by the relatively low transit temperatures in the bottom layer of the car.

### Comparison of sizes.

Restrictions have been placed upon the size of fruit permitted for eastern shipment, in an effort to improve market quality. The size 5 x 5 was limited to 25 percent of the shipments, and shipments of smaller sizes were eliminated. A comparison of Santa Rosa plums of 5 x 5 and 4 x 5 size of comparable color is shown in table 3. It was found that the larger fruit was higher in soluble solids and was generally slightly better in flavor. It appears that the elimination of small sizes is an effective way to improve the quality of Santa Rosa as well as of Beauty plums on the market.

### Color and market acceptance of fruit on arrival.

Although Santa Rosa plums of maturity 5, picked with almost full

color, had the highest flavor, in every instance they arrived with too much color for best auction display, (table 7). These results are substantiated by the holding tests (table 8). The wholesale trade preferred fruit that was one-half to three-fourths colored on arrival and objected to full color. In many cases, when shipped under good refrigeration, fruit of maturity 5 required 2 to 4 days to ripen, which indicated that it was not overripe upon arrival. Retailers did not object to high-colored fruit as long as it was firm and was not dull, dark red in color. However, it is doubtful that much fruit as ripe as this would be accepted without discount.

Santa Rosa plums one stage greener, showing one-half color when picked (maturity 4) when shipped in the warm part of the load (top layer under transit temperatures averaging 45° to 50°F., arrived with too much color for the wholesale trade and in some cases lacked firmness. In the holding tests, fruit of this maturity showed 80 to 100 percent red color after 10 days at 42° to 45°, or more than the wholesale trade preferred, indicating that lower temperatures than these were needed to retard color development. It generally arrived in acceptable condition when shipped in the cool part of the load (bottom layer) where temperatures averaged 35° to 41°F. Temperatures prevailing in the bottom layer were too cold for greener fruit, such as maturity 3. This maturity required precooling and loading in the top layer to secure desirable transit temperatures in the range of 45° to 50°. The somewhat cooler temperatures of 42° to 45° used in the holding tests generally permitted enough color development in the 10 day test period to be satisfactory. In tests 10 and 14 (nonprecooled loads) fruit of maturity 3, when shipped in the top layer where the temperatures averaged 48° to 56°, arrived with nearly full color.

There appeared to be a tendency among shippers to cool Santa Rosa plums less thoroughly than the Beauty variety with the result that in many instances too much color developed in transit. More thorough precooling of Santa Rosa plums and the loading of the most highly colored fruit in the bottom layers of the car is suggested from the results of these tests.

Decay was of no consequence except in some crates that had been frozen by salting the ice in transit.

## DUARTE PLUMS

### Maturity classification.

The minimum maturity requirement for Duarte plums was 2/3 of flesh showing red color and the surface of the plums showing some red. If the fruit had other indications of maturity it could be shipped on equivalent maturity provisions. A size regulation was also in effect, 5 x 5's being the minimum size and there was a restriction on volume of shipment of these.

Duarte plums of maturity 3 used in the tests were passed on equivalent maturity, having only $\frac{1}{4}$ to $\frac{1}{2}$ of its flesh showing pink to red color.

Maturity 4 was the designation given to plums that met the flesh color requirements and had ½ of their surface red colored.

Maturity 5 was 3/4 colored fruit.

Maturity 6, nearly full colored plums.

Flavor comparisons.

Plums having nearly full color when shipped had the best flavor, being rated excellent (table 9); 3/4 colored fruit (maturity 5) was second, being rated good. Fruit of maturity 4, showing ½ color in addition to flesh 2/3 red, was also good. Fruit passed on equivalent maturity (maturity 3) was only fair in flavor.

Color and market acceptance of fruit on arrival.

Duarte plums that were nearly full colored when harvested (maturity 6) generally arrived in good condition when shipped under low temperatures, such as prevailed in the bottom layers of the load. In top layers where the temperature was warmer, plums of this maturity arrived too ripe for the wholesaler. The wholesale trade prefers this variety showing 25 to 75 percent surface color, consequently it is not desirable to place large quantities of full colored fruit on the market. Maturity 5, 3/4 colored when shipped, arrived in good condition both in bottom and top layers in all of the test shipments (because of the good precooling given in California) and was considered the most desirable maturity for eastern shipment (table 10). In the holding tests, fruit of this maturity developed full color in some cases in 10 days at 42°F. (table 11), indicating that there is some risk of excessive color development unless the fruit is loaded in the cool part of the car. Not enough fruit of the greener maturities was shipped to warrant conclusions. It appears, however, from market observations on commercial shipments as well as from the test work, that fruit passed on equivalent maturity without much flesh color was not desirable because it lacked flavor.

Most of the test shipments of Duarte plums were well cooled (32° to 44°F. final temperature) and because of this they generally had low transit temperatures (41° to 45° in top layers in all cars but one). As indicated (table 10), this amount of refrigeration was usually adequate for the transportation of well matured fruit. With this variety as well as the others used in these tests, it would be good insurance against overripe fruit if the advanced maturities were segregated from the greener fruit and shipped in the cooler part of the load.

## TRAGEDY PLUMS

Maturity classification.

The minimum maturity requirement for the Tragedy variety is 3/4 purple color or ½ distinct purple with flesh free from the pit. In some cases, plums were passed with less color if they showed other signs of maturity such as the flesh beginning to lose its hardness, or ground

color becoming less green.

Maturity 3 was used to designate fruit falling into either of these classifications of barely passable maturity.

Maturity 4 was applied to plums showing 3/4 distinct purple.

Maturity 5 was nearly full colored fruit.

Flavor comparisons.

Too few tests were made with this variety to secure much information. Two out of the five test lots shipped were of equivalent maturity, having only 15 percent and 25 percent purple color instead of the required 50 percent. However, they were both rated as good in quality, indicating that perhaps with the Tragedy variety fruit of equivalent maturity may be satisfactory. Fruit showing 85 percent to full color was rated good to excellent in flavor.

Color and market acceptance of fruit on arrival.

The preference of the wholesale trade for plums of the Tragedy variety was fruit showing 50 to 60 percent purple color or only slightly more color than the minimum maturity has when packed. If some dark green was in evidence and if the plums were not soft, fruit of higher color would be accepted in small quantities. Nearly full colored fruit (maturity 5) shipped under low temperatures (36°F.) arrived firm to fairly firm and in good condition whereas when carried at 52° it arrived too ripe and was ready to eat. Maturity 4 (fruit 85 percent colored) arrived in good condition, without appreciable color change in the top layers of well precooled cars which had transit temperatures of 42° to 45°. In the holding test at 42°F. (table 11) Tragedy plums developed full color in 10 days indicating that cooler, bottom layer temperatures are safer for the shipment of fruit as mature as these plums were.

Fruit of maturity 3 (15 to 25 percent purple color) showed little color development when shipped in the bottom layers but developed a desirable amount of color in transit in the warmer top layer. The holding tests also indicated that temperatures of 42° to 45°F., corresponding to those usually obtained in the top layers of well refrigerated cars, were desirable for this maturity. These results suggested the advantage of segregating and loading the fruit in the car according to its maturity.

## METHODS OF CONTROLLING THE RIPENING OF PLUMS IN TRANSIT

The tests reported above indicate clearly that changes of considerable magnitude in the color and firmness of the several varieties of plums take place during their shipment to distant markets, and that these changes are usually in proportion to the transit temperatures the fruit are exposed to. Temperatures obtained in the bottom layer of most shipments (35°to 36°F.) were required to prevent much color development

which is in agreement with an observation made in earlier work by Allen, Magness and Haller (California Agricultural Experimental Station Bulletin 428, June 1927). Ripening in transit may be desirable for some maturities but low temperatures are needed to keep other maturities from becoming overripe. The point has been made that the bottom layer of the load will usually be cool enough to be suitable for the riper fruit but in some instances the entire car may be loaded with fairly mature plums and in this case thorough precooling will be needed.

A discussion of the precooling and transit refrigeration of plums based on this one season's work only, follows:

Precooling.

The relation between final precooling temperature and the average temperature of the fruit from time of loading until unloaded in New York, designated as transit temperatures, is shown in figure 1. When the cars were well cooled they generally had low transit temperatures. An exception was car 15 which had an average temperature of 51°F. in the top layer doorway stack even though it was precooled to about 40°. This shipment was made during warm weather, when the maximum temperatures were 96° in Bakersfield, 104° in Needles, 90° in Chicago and 82° in New York. The average of the maximum temperatures encountered during the trip, estimated from Weather Bureau records of cities along the route traveled, was 88°F., as compared to 79° for test car 7 which was precooled similarly but had a much lower transit temperature.

Time required to precool plums.

To obtain the desired low temperatures precooling had to be carried on for 10 to 20 hours, the time required depending principally on the initial fruit temperature. Little was accomplished with the best of equipment in 5 or 6 hours. The amount of heat removed with respect to the number of hours that loaded cars of plums were cooled is shown graphically in figure 2. Some variation between tests is to be expected due to differences in loads, outside temperatures, initial fruit temperatures, kind of precooling equipment used and how it was operated, but nevertheless, a definite trend is apparent from these tests. In 6 hours' time the fruit temperature was reduced less than 20 degrees and in 15 hours a reduction of about 35 degrees was accomplished, which in terms of final fruit temperatures would mean 40°F. if the fruit was 75° at the start of cooling. Similar results were reported by Allen and McKinnon (California Agricultural Experimental Station Bulletin 590, June 1935), who found that plums were cooled 30° to 40° in 10 to 15 hours with portable car fans when air temperatures were maintained at 35° or less. It should be made clear that the temperatures referred to in the tests reported here were those taken in the center of crates distributed throughout the load of plums. In many cars' fruit temperatures were 75° or less by the time cooling was started. (table 12). Occasionally on days when outside temperatures reached approximately 100°F., the fruit averaged 85° when loading was completed. When fruit temperatures were fairly low, the average of all precooling tests showed an hourly drop in temperature of 2° to 3°. High fruit temperatures, a cold air blast, and short cooling periods result in high cooling rates whereas in long cooling jobs, especially if the fruit is

cool to begin with, the rate of cooling is lower.

Amount of ice and salt used.

The amount of ice melted to cool loads of plums as much as 34° to 39°F. varied from 9,700 to 10,700 pounds (table 12) or approximately the equivalent of the bunker capacity of refrigerator cars. In the cars in which about 6,000 pounds of ice were melted, the loads were cooled about 22° to 33°F. The meltage of 1,000 pounds of ice generally resulted in reducing the temperature about 3° or 4°.

The value of salt was in lowering air-blast temperatures and thus speeding up cooling. It is noteworthy that where the records show heavy applications of salt, air temperatures were usually low. Frequent applications of salt, occasional barring of the ice, and replenishing the bunkers with ice are generally necessary to maintain low air temperatures and insure fast cooling.

Precooling of plums with different types of equipment.

Propeller fans installed at top bulkhead openings.

A record of a test made with a common type of portable precooling equipment, consisting of 4-bladed, 15" propeller fans driven at 3,450 r.p.m. by ½ h.p. motors, is shown in figure 3. The fans were installed in the center of a metal baffle that covered the screened opening in the top of the bunker bulkhead. Two hundred and fifty pounds of salt was added to the ice just before the fans were started. The air-blast temperature dropped rapidly to about 45°F. and then more slowly until ice and salt were added two hours later. This resulted in a drop in air blast temperature to 32° followed by a slow rise to about 34°, when another application of salt again lowered the temperature. Its average during the precooling period was about 35°, an exceedingly good record. In the 19½ hour cooling period in which there were two interruptions occasioned by reicing and switching, the fruit was cooled from a starting temperature of about 76° to a final temperature of 38° at an average rate of 2.1 degrees per hour. The top layer, exposed as it was to the air blast, cooled faster than the middle layer, and for most of the cooling period was about 3° lower in temperature.

Mechanically refrigerated trackside brine units.

Some cars of plums are cooled by mechanically refrigerated units installed alongside the railroad track. The record shown in figure 4 was obtained with this kind of equipment refrigerated from a stationary refrigerating plant. Air from the cooling unit was blown into the car through a canvas duct, the upper half of which was connected to the discharge of the fan and the lower half with its suction side. As the air passed through the trackside cooler it was refrigerated with a cold brine spray.

Car 9 (figure 4) was cooled 8 hours to a final temperature of 50°. About 16 hours would have been needed for a thorough job. The air blast dropped to about 32° in 4 hours and then rose to 40° when

another cooling unit was connected to the brine supply. The top layer cooled much faster than did the middle of the load and at the end of the 8-hour cooling it was about 6°lower in temperature.

Comparison of precooling with portable fans and equipment installed for air circulation in transit.

Some of the equipment designed for circulating air in the car while it is moving can be used for precooling by attaching electric motors to the drive shafts. A system consisting of 7 centrifugal fans installed on a shaft under the floor racks at each end of the car was compared with the conventional type of portable precooling fans. In the former system each set of fans was driven by a 3/4 h.p. motor. In operating both systems, air was circulated up through the bunker and out over the load. The test cars were loaded similarly with fruit of about the same temperature (84° and 85° at the start of cooling). In other respects such as the amount of salt and ice supplied and the time the fans were operated the two tests cars were handled alike (figure 5). The portable propeller fans cooled the fruit slightly faster than did the car equipment but towards the end of the 19-hour cooling period the latter equipment caught up with it so that there was less than 2°F. difference between the two cars at the end of the test. Lower air temperatures and faster cooling could have been obtained in both cars if the ice had been salted and barred more frequently. The test indicated that fans built into the car for air circulation in transit had sufficient capacity to be suitable for precooling plums. This conclusion was verified by another test made later in the season (car 18, table 9).

Estimating the temperature of the load.

A better method of estimating the amount of cooling that has been accomplished than the one now generally used is needed. Plums near the outside of the crates at the doorway where operators usually take temperatures may be 15° to 20° cooler than fruit in the warmer parts of the load. A truer estimate of the temperature reduction can be obtained by keeping a record of the ice meltage and estimating a 3.0° to 4.0° drop in temperature for each 1,000 pounds melted, or else by the duration of the cooling period. Some shippers wish to have a final precooling temperature for the car. A comparison was made between the average temperature of 9 positions taken throughout the load and that of plums in the middle of a crate in the top layer of the doorway stack (table 13), a position that could be reached readily with a fruit thermometer. When the direction of air circulation was from the bunker out over the top of the load, such as was the case with propeller fans installed at the top opening of the bulkhead or with car fans under the floor racks, the temperature of fruit in the top layer, doorway stack was within a degree or two of the average temperature of the load at the end of precooling periods which varied from 10 to 20 hours in the various tests. In the case of test 2, a short precooling period, in which the fans were operated only 7 hours, the top doorway position was about 7° warmer than the average. In tests with equipment delivering air to the car through the doorway, fruit temperature at this position was not so close to the average of the load, being 3° to 8° cooler. For all types of equipment tested a more accurate estimate of final precooling temperature was obtained from the average of 5 temperatures

taken in positions that could be reached with fruit thermometers. These were in top crates along the center line of the load in the bunker, quarter length and doorway stacks, and in middle and bottom layers of the doorway stack. In 15 out of 18 tests the average of these 5 temperatures was within 2° of the load average.

It should be made clear that in taking these temperatures an effort was made to reach the inside fruits of the crate. The thermometer was inserted at the inside corner of one of the four baskets and it was pushed far enough into it to puncture the paper divider between the top and middle layers of fruit.

Promptness of cooling important.

In tests 9 and 10 an excellent opportunity was afforded to compare the effect of prompt and delayed cooling. Car 9 was cooled to 50° in about 8 hours after it was loaded and the top layer was maintained at this temperature in transit, the test fruit having an average temperature of 50°. Car 10 was not precooled but the car was equipped with fans. The test fruit in the top layer, doorway stack did not reach 50° until 2 days after it was loaded (figure 6). Because of air circulation and frequent replenishing of bunkers with ice and salt, the top layer in this car continued to drop in temperature and was maintained at 40° for the last 5 days of the trip. The test fruit had an average temperature of 48°. Despite similar average temperatures (50° and 48°) the condition of the fruit from the two cars was markedly different upon arrival. Santa Rosa plums of maturity 3 (minimum maturity) shipped in non-precooled car 10 had 95 percent red color on arrival and were too far advanced in maturity whereas those shipped in promptly cooled car 9 were 65 percent colored and were in good condition for the market (table 7). Plums of riper maturity when shipped had about the same amount of color in both cars on arrival but the fruit from the non-precooled shipment was noticeably softer than the promptly cooled fruit.

These comparisons bring up several important points which need further investigation, such as the time required to cause noticeable ripening at various temperatures and whether or not ripening is faster immediately after picking than it is later during the transit period.

Effect of air circulation in transit.

In test 10 the value of air circulation in transit in removing heat from the load and in maintaining low temperatures was demonstrated (figure 6). It was found, however, that cooling in transit was not fast enough to take the place of precooling. Another point of interest is the effect of air circulation in maintaining uniform temperatures throughout the load. The temperature records of positions in the top and bottom layers of well precooled standard car and in a moderately cooled fan car are shown in figures 7 and 8 respectively. In the standard car the top layer was about 10° warmer than the bottom layer as contrasted with only a few degrees difference in the car equipped with an air circulation system. The relatively low top layer temperatures found in fan cars suggests the possibility of shipping plums of advanced maturity successfully in all layers of the load in contrast with the necessity of using only the bottom layers when this maturity is shipped in standard cars.

## SUMMARY

Beauty plums with 10 to 50 percent pink or red color, without soft tips were preferred by the wholesale trade. For fruit of barely passing maturity (yellowish green to straw, or trace of pink at the tips) bottom layer temperatures were too cold; such fruits were best when shipped in the top layer of the load. Plums one stage riper, showing 2 to 10 percent pink to red color, required cool bottom layer temperatures and plums even riper than these, with 15 to 25 percent of their surface pink to red, likewise arrived in good condition without too much color when they were shipped in the bottom layers of the load. Plums of these two riper maturities had much better flavor than the fruit of minimum maturity. Large plums were higher in flavor and soluble solids than small fruit of the same color. Little decay developed in transit and only small amount during ripening. Decay was slightly more prevalent in fruit from the warm part of the load and in the advanced maturities.

Santa Rosa plums showing $\frac{1}{2}$ to 3/4 red color were preferred by the wholesale trade although retailers did not object to high-colored fruit if it was firm and not dull, dark red. Transit temperatures required were dependent upon the maturity at which the fruit was harvested. Plums $\frac{1}{4}$ to $\frac{1}{2}$ red, barely meeting minimum maturity requirements, needed the top layer temperatures of the precooled cars to permit some color development in transit; fruit riper than this required bottom layer temperatures. The best flavor was obtained in plums fully colored when shipped, but the wholesale trade objected to handling fruit with as much color as this, although in many cases, when shipped in the cool part of the load, it required 2 to 4 days to ripen after arrival.

Duarte plums with red flesh color and 25 to 75 percent surface color were preferred by the wholesale trade. Plums showing 3/4 color when packed proved to be a desirable maturity, having good flavor and arriving without too much color when shipped either in the bottom layer of the load or in the top layer of well refrigerated cars. Riper, full-color fruit, acceptable only in limited quantities, needed the cooler bottom-layer temperatures. Plums that did not have the required 2/3 of flesh showing flesh color lacked flavor and market appeal.

Tragedy plums showing 50 to 60 percent purple color on arrival were preferred by the wholesale trade. Fruit of minimum maturity, having $\frac{1}{2}$ purple color when shipped, or fruit passed on equivalent maturity, developed enough color in transit in top layers to satisfy these market preferences and its quality was good. Bottom layer temperatures were too cold for it. Riper fruit, showing 85 percent color when packed, needed the cool temperatures obtained by shipping it in bottom layers or in the top layers of well precooled cars.

The market preference for fruit of uniform maturity in each crate, and the wide difference in the temperature requirements of the various maturities, indicate that it would be desirable to segregate maturities at time of packing and load the riper fruit in the bottom layers of the car.

The amount of precooling the car received had a direct influence on the transit temperature of the fruit.

About 15 hours precooling were required to obtain a 35° reduction in the temperature of the load. The average of all precooling tests indicated an hourly drop of 2° to 3°.

The meltage of 1,000 pounds of ice resulted in lowering the temperature of the load 3° to 4°, as a general average.

A fan system built into the car had sufficient capacity to precool plums approximately as fast as the conventional type portable propeller fans.

The final precooling temperature of a carload of plums can be estimated on the basis of the ice melted, 3° to 4° reduction being obtainable per 1,000 pounds melted, or else on the basis of the time the car is cooled, calculating 2° to 3° hourly reduction.

A relatively accurate method for taking the temperature of the load is suggested.

Plums promptly cooled developed less color and softened less in transit than comparable fruit more slowly cooled but exposed to lower temperatures during the latter part of the transit period.

In cars equipped with fans but not precooled, cooling was not fast enough to take the place of precooling but this equipment maintained fairly uniform temperatures throughout the load.

## ACKNOWLEDGEMENTS

The packing and shipping facilities furnished by various shipping firms and the cooperation of receivers, auction houses, railroads, car companies and precooling agencies are gratefully acknowledged.

* * * * * * * * * * * * * * * * * * *

TABLE 1. TEST SHIPMENTS OF PLUMS MADE IN 1941 INVESTIGATIONS 1/

| Test No. | Transit period | Shipping point | Variety shipped and number of test crates | Hours pre-cooled | Final 2/ precooling temp. °F | Precooling immediate or delayed 3/ | Refrigeration 4/ |
|---|---|---|---|---|---|---|---|
| 1 | 5/29-6/3 | Reedley | Beauty 5 | None | ---- | ---- | Initial ice only |
| 2 | 5/30-6/9 | Kern Co. | Beauty 6 | 7 | 53 | Immediate | One reicing |
| 3 | 6/1-11 | Reedley | Beauty 5 | 7¼ | 66 | Immediate | Standard ref. 5/ |
| 4 | 6/3-13 | Kern Co. | Beauty 6 Formosa 2 | 17 | 49 | Immediate | One reicing |
| 5 | 6/5-16 | Reedley | Beauty 6 | 7½ | 66 | Immediate | Standard ref. 3% salt. 5/ |
| 6 | 6/9-19 | Loomis | Beauty 10 | 12½ | 37 | Delayed | Standard ref. |
| 7 | 6/9-19 | Loomis | Beauty 10 | 18¼ | 38 | Immediate | Standard ref. |
| 8 | 6/10-20 | Kern Co. | Santa Rosa 6 | 14 | 50 | Immediate | One reicing 5/ |
| 9 | 6/13-23 | Reedley | Formosa 2 S. Rosa 6 | 8¼ | 50 | Immediate | Two reicings |
| 10 | 6/13-23 | Reedley | S. Rosa 6 | None | ---- | ---- | Standard ref. 3% salt. 5/ |
| 11 | 6/14-24 | Vacaville | Beauty 13 | 12-3/4 | 37 | Immediate | Two reicings |
| 12 | 6/17-30 | Kern Co. | S. Rosa 6 | 16¼ | 48 | Immediate | One reicing |
| 13 | 6/20-7/2 | Loomis | Beauty 4 S. Rosa 6 | 20 | 36 | Immediate | Standard ref. 2% salt. |
| 14 | 6/21-7/2 | Reedley | S. Rosa 6 | None | ---- | ---- | Standard ref. 3% salt. 5/ |
| 15 | 6/28-7/9 | Hanford | Tragedy 4 | 10½ | 38 | Delayed | One reicing |
| 16 | 7/1-11 | Newcastle | S. Rosa 4 Duarte 6 | 13½ | 44 | Delayed | One reicing |
| 17 | 7/5-14 | Lodi | Tragedy 6 Duarte 4 | 12 | 36 | Immediate | Standard ref. |
| 18 | 7/3-14 | Lodi | Tragedy 6 Duarte 4 | 14 | 41 | Immediate | Standard ref. 5/ |
| 19 | 7/7-18 | Loomis | Duarte 8 | 26-3/4 | 32 | Immediate | Two reicings 5/ |
| 20 | 7/7-16 | Newcastle | Duarte 8 | 11 | 35 | Delayed | Standard ref. |

1/ Test 1 was an express shipment, all others were by freight. Test 20 destined Cleveland, all others New York City.
2/ Average of 9 positions in load in top, middle and bottom layers.
3/ Delayed cars were precooled on day after loading was finished.
4/ All cars initially iced, replenished after precooling and reiced once, twice or 10 to 12 times (standard ref.) in transit.
5/ Air circulation in transit with Preco Blowers.

TABLE 2. EFFECT OF MATURITY OF BEAUTY PLUMS ON FLAVOR WHEN RIPENED
1941

| Test No. | Shipping Point | Date Shipped 1941 | Average transit temperature | | Flavor when ripe 1/ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Maturity 3 Straw tip to trace of pink | | Maturity 4 2% to 10% pink | | Maturity 5 and 5y 15% to 23% pink 2/ | |
| | | | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway |
| | | | °F | °F | | | | | | |
| 2 | Kern Co. | 5/30 | 39 | 50 | 26 | 23 | 48 | 52 | | |
| 4 | do | 6/3 | 38 | 47 | 43 | 40 | 57 | 51 | | |
| 1 | Reedley | 5/29 | 44 | 61 | -- | 34 | 58 | 52 | | |
| 3 | do | 6/1 | 44 | 47 | 42 | 37 | 51 | 45 | 50 | -- |
| 5 | do | 6/5 | 40 | 41 | 32 | 35 | 45 | 42 | 59 | 59 |
| 6 A | Loomis | 6/9 | 40 | 43 | 27 | 47 | 37 | 48 | 60 | 48 |
| 6 B | do | do | 40 | 43 | 28 | 47 | -- | -- | 62 | 47 |
| 7 A | do | do | 35 | 42 | 30 | 30 | 47 | 53 | -- | -- |
| 7 B | do | do | 35 | 42 | 16 | 43 | -- | -- | 55 | 47 |
| 7 C | do | do | 35 | 42 | 23 | 28 | -- | -- | -- | -- |
| 13 | do | 6/20 | 35 | 45 | -- | -- | 53 | 43 | 63 | 33 |
| 11 D | Vacaville | 6/14 | 37 | 47 | 23 | 15 | 27 | 15 | 25 | 52 |
| 11 E | do | do | 37 | 47 | 18 | 20 | 22 | 25 | 30 | 33 |
| | Average | | | | 28 | 33 | 45 | 42 | 50 | 46 |

1/ Flavor index 1-24 poor, 25-49 fair, 50-74 good, 75-100 excellent.
2/ Maturity 5 predominantly yellow green, 5y predominantly green yellow to light yellow.

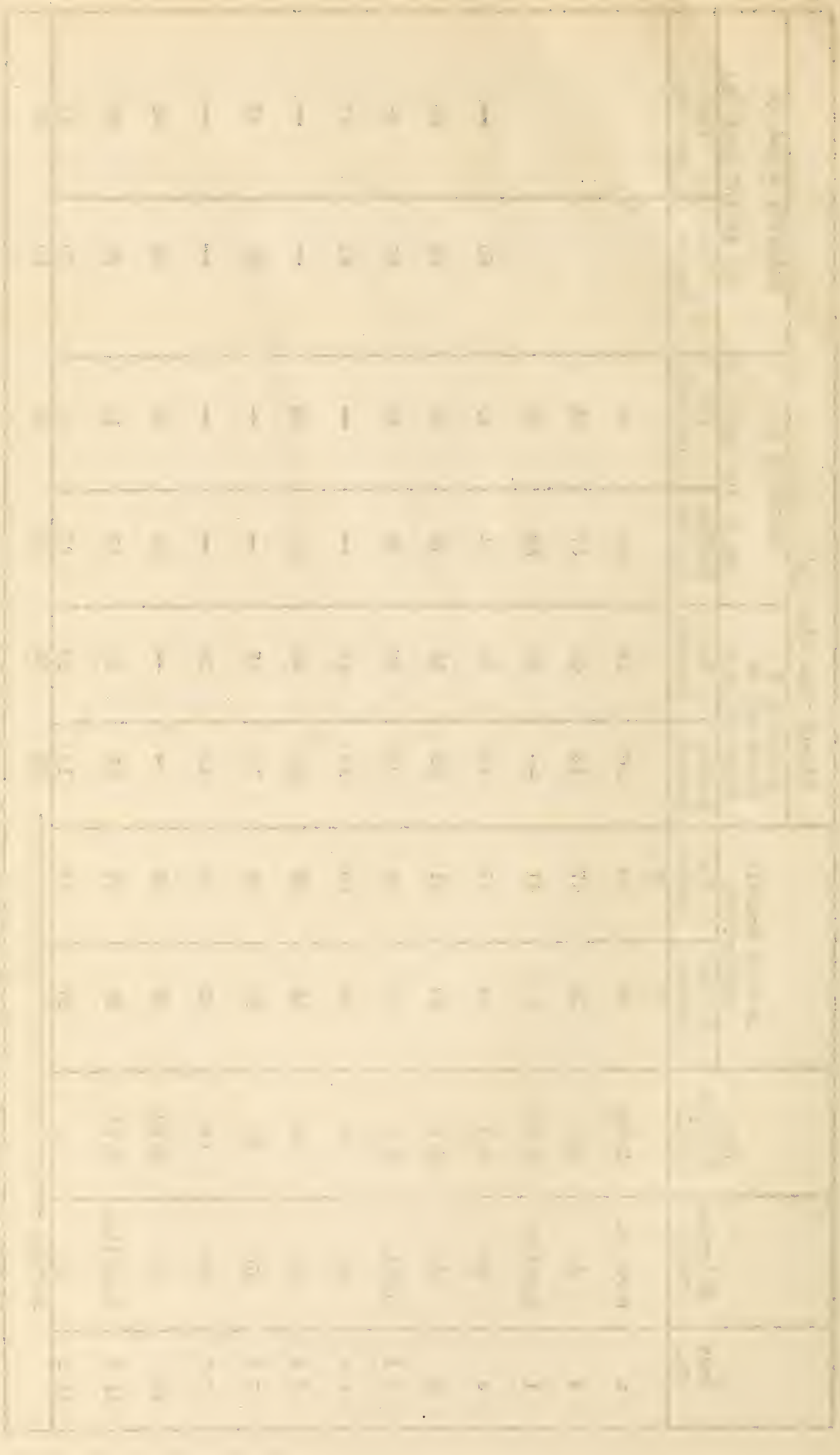


TABLE 3. THE RELATION OF SIZE TO SOLUBLE SOLIDS AND FLAVOR OF PLUMS 1941

| Variety | District | Date Harvested | Maturity | Soluble solids | | | Flavor | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 5x5's | 4x5's | 4x4's | 5x5's | 4x5's | 4x4's |
| | | | | Pct. | Pct. | Pct. | | | |
| Beauty | Kern Co. | May 30 | 2 | 7.6 | 8.0 | 8.5 | Poor | Poor | Poor |
| do | do | May 30 | 3 | 7.1 | 8.1 | 8.4 | Poor | Fair | Fair |
| do | Fresno Co. | June 1 | 4 | 9.0 | 10.1 | 9.9 | Fair | Good | Good |
| do | do | June 1 | 5 | 9.0 | 10.3 | 11.0 | Fair | Fair | Fair |
| do | Kern Co. | June 3 | 3 | 8.8 | 9.8 | 9.8 | Fair | Fair | Fair |
| do | do | June 3 | 4 | 8.4 | 8.9 | 10.5 | Poor | Fair | Fair |
| do | Fresno Co. | June 5 | 4 | 9.4 | 9.4 | 9.8 | Poor | Poor | Fair |
| | | Average ---------- | | 8.4 | 9.2 | 9.7 | | | |
| Santa Rosa | Kern Co. | June 10 | 3 | 11.1 | 11.5 | - | Fair | Good | - |
| do | do | June 10 | 4 | 11.1 | 11.9 | - | Good | Good | - |
| do | do | June 10 | 5 | 12.2 | 12.6 | - | Good | Good | - |
| do | Fresno Co. | June 21 | 3 1/ | 11.5 | 12.3 | - | Fair | Fair | - |
| | | | 3 | 12.2 | 12.6 | - | Fair | Good | - |
| | | | 5 | 13.2 | 14.0 | - | Good | Good | - |
| | | Average ------ | | 10.9 | 12.5 | | | | |

1/ Passed on equivalent maturity.

TABLE 4. RIPENING OF BEAUTY PLUMS IN TRANSIT AS INFLUENCED BY PRECOOLING AND TRANSIT TEMPERATURES.
1941

| Test Lot | Average temp. of load after pre-cooling | Average transit temperature | | Condition for market and percent ripe color upon arrival 1/ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Maturity 3 Straw tip to trace of pink | | | | Maturity 4 2% to 10% pink | | | | Maturity 5 15% to 25% pink | | | |
| | | Bottom bunker | Top doorway | Bottom bunker | | Top doorway | | Bottom bunker | | Top doorway | | Bottom bunker | | Top doorway | |
| | °F | °F | °F | Condition | Color | Condition | Color | Condition | Color | Condition | Color | Condition | Color | Condition | Color |
| 3 | 66 | 44 | 47 | sl. green | 10 | good | 35 | sl. ripe | 80 | sl. ripe | 75 | sl. ripe | 75 | --- | --- |
| 5 | 66 | 40 | 41 | green | tr. | green | tr. | sl. green | 3 | good | 10 | good | 25 | sl ripe | 30 |
| 2 | 53 | 39 | 50 | green | tr. | good | 50 | sl. green | 6 | sl. ripe | 88 | --- | --- | --- | --- |
| 4 | 49 | 38 | 47 | green | tr. | good | 8 | sl. green | 15 | sl. ripe | 70 | --- | --- | --- | --- |
| 6A | 37 | 40 | 43 | green | 0 | sl. green | 5 | sl. green | 5 | sl. ripe | 35 | sl. ripe | 25 | ripe | 60 |
| 6B 2/ | do | do | do | sl. green | 2 | sl. ripe | 32 | --- | --- | --- | --- | sl. ripe | 38 | ripe | 75 |
| 7A | 38 | 35 | 42 | green | tr. | good | 30 | good | 15 | ripe | 90 | --- | --- | --- | --- |
| 7B | do | do | do | green | 1 | sl. ripe | 35 | --- | --- | --- | --- | good | 25 | ripe | 75 |
| 7C 3/ | do | do | do | green | 0 | sl. green | 5 | --- | --- | --- | --- | --- | --- | --- | --- |
| 11D | 37 | 37 | 47 | green | 1 | good | 35 | good | 11 | ripe | 85 | good | 30 | ripe | 90 |
| 11E | do | do | do | green | tr. | good | 35 | good | 10 | ripe | 80 | good | 30 | ripe | 99 |
| 13 | 36 | 35 | 45 | --- | --- | --- | --- | sl. green | 4/ 7 | ripe | 90 | good | 5/ 40 | ripe | 100 |

1/ Fruit classed as ripe usually had too much color for wholesale trade but in some cases was so classed because it lacked firmness. Green fruit lacked color and was hard or firm. Color was pink to red, usually increasing in intensity with amount.

2/ Showed trace of pink when packed.

3/ Greenest of 3 lots when packed. 10% light green on shoulder.

4/ 9% freezing enroute.

5/ 2% freezing enroute

TABLE 5. COLOR AND FIRMNESS CHANGES IN BEAUTY PLUMS
HELD AT 42° TO 45°F. FOR 10 DAYS, DAVIS AND FRESNO CALIFORNIA

(Comparable test boxes of fruit to those shipped to New York, May and June, 1941)

| Date | Test Lot | Maturity | Color When Harvested — Percentage of Surface | | | | | Color and firmness — After 10 days-42°F | | After 2 add'l days at 70°F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lt. Gr. | Yel. Gr. | Gr. yel | Yel low | Pink or Red | Pct. surface col'd | Firmness* | Pct. surface col'd | Firmness* |
| 5/30 | 2 | #2 lt.gr. | 50 | 50 | 0 | | 0 | 0 | H - F | | |
| | 2 | #3 yel.gr. | | 95 | | 5 | 0 | 5 | mostly F | | |
| | 2 | #4 yel.gr. pink tip | | | | | | | (some S) | | |
| 6/3 | 4 | #3 yel.gr. | 10 | 80 | 10 | | 0 | 2 | mostly F | | |
| | 4 | #3 str.tip | 0 | 50 | 20 | 3 | 2 | 15 | mostly F | | |
| | 4 | #4 gr.yel. | 0 | 50 | 30 | 10 | 10 | 30 | FF to S | | |
| 6/5 | 5 | #3 yel.gr. | 0 | 75 | 25 | 0 | 0 | 2 | F | | |
| | 5 | #4 gr.yel. amber tip | 0 | 10 | 80 | 7 | 3 | 15 | F | | |
| | 5 | #5 gr.yel. pink tip | 0 | 0 | 75 | 10 | 15 | 55 | FF to S | | |
| 6/9 | 6 | #3 str.tip | | 50 | 48 | 2 | 0 | 2 | F | 100 | FF |
| | 6 | #4 pink tip | | 15 | 75 | 10 | 0 | 25 | FF | 100 | S |
| | 6 | #5 ¼ color | | 0 | 65 | 10 | 25 | 50 | FF | 100(A) | S |
| | 7 | #3 yel.gr. to straw | 10 | 0 | 85 | 5 | | 50 | FF | 100 | FF |
| | 7 | #5 pink tip to 25% color | 0 | 0 | 65 | 10 | 25 | 70 | FF | 100 | S |
| 6/14 | 11 | #3 str.tip | 15 | 60 | 15 | 10 | | 20 | FF | 80 | FF |
| | 11 | #4 pink tip | | 20 | 40 | 30 | 10 | 45 | FF | 100 | S |
| | 11 | #3 str.tip | 10 | 60 | 20 | 10 | | 25 | F-FF | 100 | FF |
| | 11 | #4 pink tip | | 10 | 60 | 20 | 10 | 60 | FF | 100 | S |
| | 11 | #5 ¼ color | | | 65 | 10 | 25 | 80 | FF | 100 | S |
| 6/20 | 13 | #4 gr.yel. pink tip | | 10 | 75 | 10 | 5 | 95 | F-FF | 100 | S |
| | | #5 gr.yel. ¼ color | | | 15 | 50 | 35 | 50 | F | 100(A) | S |

* H - hard
F - firm
FF - fairly firm
S - soft
A - fruit dark red

TABLE 6. EFFECT OF MATURITY OF SANTA ROSA PLUMS ON FLAVOR WHEN RIPENED. 1941

| Test No. | Shipping Point | Date Shipped 1941 | Average transit temperature | | Flavor when ripe 1/ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Maturity 3 | | Maturity 3 | | Maturity 4 | | Maturity 5 | |
| | | | | | Mature but less than ¼ color | | ¼ color | | ½ color | | Nearly full color | |
| | | | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom Bunker | Top doorway |
| | | | °F | °F | | | | | | | | |
| 8 | Kern Co. | 6/10 | 40 | 47 | | | 43 | 47 | 70 | 68 | 78 | 73 |
| 12 | do | 6/17 | 39 | 46 | 60 | 75 | | | 70 | 70 | 75 | 78 |
| 9 | Reedley | 6/13 | -- | 50 | 23 | 48 | | | 43 | 48 | 73 | 63 |
| 10 | do | do | 41 | 48 | 70 | 65 | | | 77 | 75 | 82 | 87 |
| 14 | do | 6/21 | 41 | 56 | 50 | 75 | 65 | 73 | | | 87 | 95 |
| 13 | Loomis | 6/20 | 35 | 45 | | | 48 | 48 | 53 | 55 | 87 | 85 |
| 16 | Nestle | 7/1 | 37 | 48 | | | | | 57 | 60 | 85 | 83 |
| Average | | | | | 51 | 66 | 52 | 56 | 62 | 63 | 81 | 80 |

1/ Flavor index, 1-24 poor, 25-49 fair, 50-74 good, 75-100 excellent.

TABLE 7. RIPENING OF SANTA ROSA PLUMS IN TRANSIT AS INFLUENCED BY PRECOOLING AND TRANSIT TEMPERATURES. 1941

| Test No. | Average temp. of load after cooling | Ave. transit temperature | | Condition for market and percent ripe color upon arrival. 1/ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Maturity 3x 2/ Mature-less than ¼ color | | | | Maturity 3 ¼ color | | | | Maturity 4 ½ color | | | |
| | | Bottom bunker | Top doorway | Bottom bunker | | Top doorway | | Bottom bunker | | Top doorway | | Bottom bunker | | Top doorway | |
| | | | | Condition | Color | Condition | Color | Condition | Color | Condition | Color | Condition | Color | Condition | Color |
| | °F | °F | °F | | | | | | | | | | | | |
| 14 | not cooled | 41 | 56 | good | 55 | ripe | 100 | good | 70 | ripe | 100 | -- | -- | -- | -- |
| 10 | not cooled | 41 | 48 | good | 57 | ripe | 95 | -- | -- | -- | -- | good | 80 | ripe | 90 |
| 9 | 50 | -- | 50 | green | 10 | good | 65 | -- | -- | -- | -- | good | 60 | sl.ripe | 90 |
| 8 | 49 | 40 | 47 | -- | -- | -- | -- | sl.green | 40 | sl.green | 55 | good | 65 | ripe | 85 |
| 12 | 48 | 39 | 46 | green | 15 | good | 80 | -- | -- | -- | -- | good | 60 | ripe | 92 |
| 16 | 44 | 37 | 48 | -- | -- | -- | -- | -- | -- | -- | -- | sl.ripe 4/ | 99 | ripe | 100 |
| 15 | 36 | 35 | 45 | -- | -- | -- | -- | green 3/ | 35 | good | 90 | sl.green | 60 | sl.ripe | 96 |

1/ Fruit classed as ripe usually had too much color for wholesale trade but in some cases it was so classed because of lack of firmness. Fruit classed as green or slightly green shrivelled on ripening, or became rubbery or ripened unevenly. It usually had enough color to suit the trade. Ripe color referred to was pink to red usually increasing in intensity with amount.

2/ Passed on equivalent maturity, i.e.--usually ground color and firmness.

3/ 14% freezing enroute.

4/ 6% freezing enroute.

TABLE 8. COLOR AND FIRMNESS CHANGES IN SANTA ROSA PLUMS HELD AT 42° to 45°F. FOR 10-DAYS, DAVIS OR FRESNO, CALIFORNIA 1941

(Comparable test boxes of fruit to those shipped to New York, June 10-July 1, 1941)

| Date | Test lot | Maturity | Color when harvested Percentage of surface | | | | Color and firmness After 10 days-42 F. | | After 2 add'l days at 70°F. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Yel. gr. | Gr. yel. | Yel-low | Pink or red | Pct. surface col'd | Firmness* | Pct. surface col'd | Firmness* |
| 6/10 | 8 | #3 equiv. maturity | 30 | 40 | | 30 | 55 | mostly H | | |
| | 8 | #4 ½ red | 10 | 30 | | 60 | 85 | mostly H | | |
| | 8 | #5 full red | | 5 | | 95 | 95 | mostly F | | |
| 6/13 | 9-10 | #3 equiv. maturity | 25 | 72 | | 3 | 50 | F | | |
| | 9-10 | #4 ½ red | 10 | 30 | | 60 | 85 | F | | |
| | 9-10 | #5 full red | 10 | | | 90 | 100 | F | | |
| 6/19 | 12 | #3 equiv. maturity | 10 | 70 | 10 | 10 | 20 | H | | |
| | 12 | #4 ½ red | | 40 | 10 | 50 | 80 | H | | |
| | 12 | #5 full red | | 5 | | 95 | 95 | F | | |
| 6/20 | 13 | #3 equiv. maturity | 5 | 60 | | 35 | 85 | F | 100 | |
| | 13 | #4 ½ red | | 40 | | 60 | 95 | FF-S | 100 | |
| | 13 | #5 full red | | | 5 | 95 | 100 | FF | 100 (dark) | |
| 6/21 | 14 | #3 equiv. maturity | 40 | 40 | 10 | 10 | 600 | F | | |
| | 14 | #4 ½ red | | 50 | 30 | 20 | 90 | F | | |
| | 14 | #5 full red | | | 5 | 95 | 100 | F | | |
| 7/1 | 16 | #4 ½-3/4 rod | | 40 | | 60 | 100 | FF | 100 | FF |
| | 16 | #5 full red | | | | | 100 | FF-S | 100 | FF-S |

* H - hard
F - firm
FF - fairly firm
S - soft
A - fruit dark red

TABLE 9. EFFECT OF MATURITY OF DUARTE PLUMS ON FLAVOR
1941

| Test No. | Shipping point | Date shipped | Average transit temperature | | Flavor when ripe 1/ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Maturity 3 2/ Less than ½ color | | Maturity 4 ½ color 3/ | | Maturity 5 3/4 color 3/ | | Maturity 6 Nearly full red 3/ | |
| | | | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway | Bottom bunker | Top doorway |
| 16 | Newcastle | 7/1 | 37 | 48 | | | 55 | 65 | 82 | 70 | 88 | 90 |
| 19F | Loomis | 7/7 | 39 | 41 | 25 | 33 | | | 43 | 55 | | |
| 19G | do | do | 39 | 41 | | | | | 73 | 70 | 64 | 67 |
| 18 | Lodi | 7/3 | 42 | 45 | | | 62 | 77 | 68 | 82 | | |
| | Average | | | | 25 | 33 | 58 | 71 | 66 | 69 | 76 | 78 |

1/ Flavor index 1-24 poor, 25-49 fair, 50-74 good, 75-100 excellent.
2/ Flesh color ¼ to ½ pink, passed on equivalent maturity usually firmness.
3/ Flesh color more than 2/3 red.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

TABLE 10. RIPENING OF DUARTE PLUMS IN TRANSIT AS INFLUENCED BY PRECOOLING AND TRANSIT TEMPERATURES. 1941

| Test No. | Average temp. of load after pre-cooling | Average transit temperature | | Condition for market and percent ripe color upon arrival. 1/ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Maturity 3 Less than ½ color 2/ | | | | Maturity 4 ½ color 3/ | | | | Maturity 5 3/4 color 3/ | | | |
| | | Bottom bunker | Top doorway | Bottom bunker | | Top doorway | | Bottom bunker | | Top doorway | | Bottom bunker | | Top doorway | |
| | °F | °F | °F | Condition | Color | Condition | Color | Condition | Color | Condition | Color | Condition | Color | Condition | Color |
| 16 | 44 | 37 | 48 | -- | -- | -- | -- | green | 50 | good | 80 | good | 75 | ripe | 95 |
| 18 | 41 | 42 | 45 | -- | -- | -- | -- | sl.green | 50 | sl.green | 60 | good | 80 | good | 85 |
| 19F | 32 1/ | 39 | 41 | green 4/ | 15 | green 4/ | 25 | -- | -- | -- | -- | green 4/ | 80 | good 4/ | 80 |
| 19G | 32 | 39 | 41 | -- | -- | -- | -- | -- | -- | -- | -- | good 4/ | 80 | good 4/ | 78 |
| 20F | 35 | 37 | 45 | -- | -- | -- | -- | -- | -- | -- | -- | good | -- | good | -- |
| 20G | 35 | 37 | 45 | -- | -- | -- | -- | -- | -- | -- | -- | good | -- | good | -- |

1/ Fruit classed as ripe usually had too much color for wholesale trade or lacked firmness. Green fruit lacked color and was hard or firm. Color referred to was mottled pink to red, intensity increasing with amount.
2/ Flesh color ¼ to ½ pink, passed on equivalent maturity, usually firmness.
3/ Flesh color more than 2/3 red.
4/ Some freezing damage, slight to 15 percent.

TABLE 11. COLOR AND FIRMNESS CHANGES IN DUARTE AND TRAGEDY PLUMS HELD AT 42° TO 45°F. FOR 10-DAYS, DAVIS OR FRESNO, CALIFORNIA

(Comparable test boxes of fruit to those shipped to New York July 1-8, 1941)

| Date | Test lot | Maturity | Color when harvested — Percentage of surface | | | Color and firmness — After 10 days - 42°F. | | After 2 add'l days - 70°F. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Yellow green | Green Yellow | Pink or blue | Pct. surface colored | Firmness* | Pct. surface colored | Firmness* |
| | | | | | DUARTE | | | | |
| 7/1 | 16 | #4 ¼ to ½ pink | 50 | | 50 | 80 | F | 100 | FF |
| | 16 | #5 ½ to 3/4 pink | 10 | | 90 | 100 | FF | 100 | FF |
| | 16 | #6 3/4 to full pink | 15 | | 85** | 100 | S | 100 | S |
| 7/3 | 17-18 | #4 3/4 pink | 20 | | 80 | 95 | F | 100 | FF to S |
| | 17-18 | #5 3/4 to full pink | 5 | | 95 | 100 | F | 100 | S |
| 7/8 | 19-20 | #3 ¼ pink | 75 | | 25 | 25 | F | 90 | FF to S |
| | | #5 3/4 to full pink | 25 | | 75** | 90 | F | 100 | FF to S |
| | | #5 3/4 to full pink | 25 | | 75 | 75 | F | 100 | FF |
| | | #6 full color | | | 100 | 100 | F to FF | 100 | FF to S |
| | | | | | TRAGEDY | | | | |
| 6/28 | 15 | #3 ¼ color | 60 | 25 | 15 | 50 | FF | 100 | FF to S |
| | | #5 full color | | 5 | 95 | 100 | FF | 100 | FF to S |
| 7/3 | 17-18 | #3 ¼ color | 75 | | 25 | 85 | FF | 100 | S |
| | | #4 3/4 color | 15 | | 85 | 100 | FF | 100 | S |
| | | #5 full color | 5 | | 95 | 100 | FF to S | 100 | S |

*H - hard S - soft ** Flesh full red
F - firm A - fruit dark red
FF - fairly firm

TABLE 12. SUMMARY OF DATA OBTAINED DURING PRECOOLING OF PLUMS
1941

| Test No. | Cooling period | Average fruit temp. | | Temp. drop | | Salt used | Ice melted | Temp. drop per 1000 lbs. of ice melted | Average temp. of air blast | No. of fans | Location of fans |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Start | Finish | Total | Per hr. | | | | | | |
| | Hours | °F | °F | °F | °F | lbs. | lbs. | °F | °F | | |
| 2 | 7 | 71.2 | 53.2 | 18.0 | 2.5 | 250 | 3,500 | 5.1 | 40.5 | 2 | Bunker |
| 5 | 7 | 76.2 | 66.4 | 9.8 | 1.3 | 250 | 4,655 | 2.1 | 44.3 | 4 | Bracing 1/ |
| 3 | 7½ | 72.2 | 66.2 | 6.0 | .8 | 250 | 3,580 | 1.7 | 45.2 | 4 | Bracing 1/ |
| 9 | 8¼ | 73.7 | 50.0 | 23.7 | 2.9 | - | - | - | 38.4 | 1 | Doorway 2/ |
| 15 | 10½ | 66.6 | 37.7 | 28.9 | 2.8 | 848 | 6,000 | 4.8 | 34.7 | 2 | Bunker |
| 20 | 11 | 70.4 | 34.9 | 35.5 | 3.2 | - | - | - | 31.9 | 1 | Doorway 2/ |
| 17 | 11½ | 71.0 | 36.5 | 34.5 | 3.0 | - | - | - | 32.8 | 1 | Doorway 2/ |
| 6 | 12½ | 65.8 | 36.5 | 29.3 | 2.3 | - | - | - | 33.6 | 1 | Doorway 2/ |
| 11 | 12-3/4 | 70.5 | 37.3 | 33.2 | 2.6 | 530 | 8,670 | 3.8 | 33.0 | 4 | Bunker |
| 16 | 13½ | 67.8 | 43.7 | 24.1 | 1.8 | 640 | 6,250 | 3.9 | 37.5 4/ | 2 | Bunker |
| 18 | 14 | 62.8 | 40.6 | 22.2 | 1.6 | 636 | 6,000 | 3.7 | 26.2 | 8 | Under floor rack 3/ |
| 12 | 16½ | 80.6 | 48.0 | 32.6 | 2.0 | 375 | 6,380 | 5.1 | 47.8 | 2 | Bunker |
| 4 | 17 | 78.8 | 49.4 | 29.4 | 1.7 | 500 | 6,460 | 4.5 | 44.3 | 2 | Bunker |
| 8x | 17¼ | 85.4 | 47.7 | 37.7 | 2.2 | 500 | 9,660 | 3.9 | 43.9 | 2 | Bunker |
| 8 | 18¼ | 84.3 | 48.9 | 35.4 | 1.9 | 500 | 10,100 | 3.5 | 41.6 | 8 | Under floor rack 3/ |
| 7 | 18¼ | 76.3 | 37.5 | 38.8 | 2.1 | 620 | 10,745 | 3.6 | 34.6 | 2 | Bunker |
| 3 | 20 | 69.6 | 36.1 | 33.5 | 1.7 | 700 | 10,255 | 3.3 | 38.4 | 2 | Bunker |
| 9 | 26-3/4 | 81.5 | 31.9 | 49.6 | 1.8 | - | - | - | 5/ | | |

1/ Preco car blowers idle during precooling.
2/ Cooled by mechanical refrigeration.
3/ Preco car equipment.
4/ 19° minimum for 1 hour.
5/ Precooled in warehouse 18-3/4 hours, air blast 46°, and again in car with mechanical refrigeration for 8 hours, average air temperature 27°, minimum 20°F.

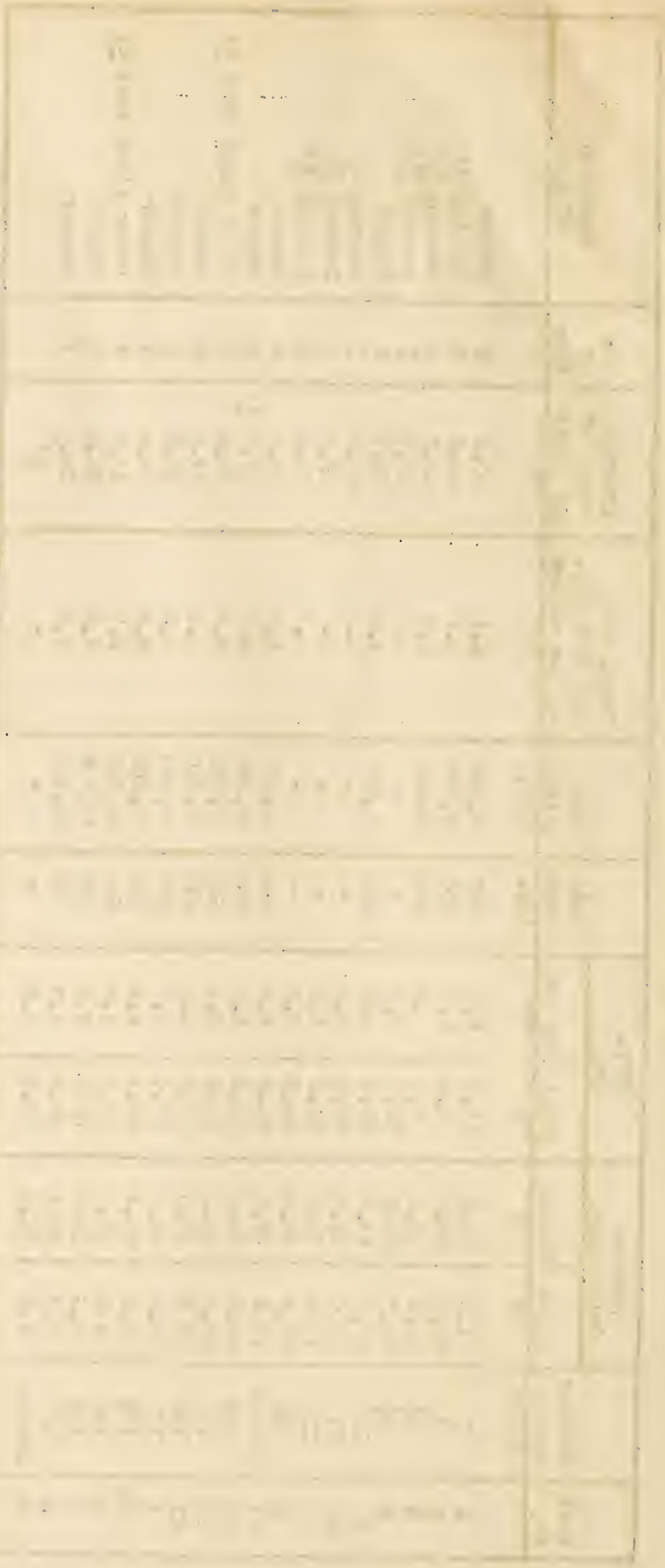


TABLE 13. TEMPERATURES OF VARIOUS POSITIONS IN PLUM LOADS AS COMPARED TO THEIR AVERAGE TEMPERATURES, 1941

| Test | Precooling method | Hours cooled | Average temp. 1/ | Top doorway temp. compared to average | Five outside crates compared to average 2/ |
|---|---|---|---|---|---|
| | | | °F | °F | °F |
| 2 | Propellor fans top bulkhead opening | 7 | 53.2 | +6.8 | -0.4 |
| 15 | " | 10½ | 37.7 | +2.1 | +0.2 |
| 11 | " | 12-3/4 | 37.3 | -2.4 | -1.4 |
| 16 | " | 13½ | 43.7 | 0.0 | -3.0 |
| 12 | " | 16½ | 48.0 | +2.6 | +0.1 |
| 4 | " | 17 | 49.4 | -0.5 | -0.5 |
| 8x | " | 17¼ | 47.7 | -2.1 | -1.8 |
| 7 | " | 18¼ | 37.5 | -2.3 | -1.5 |
| 13 | " | 20 | 36.1 | --- | -1.6 |
| 5 | Fans blowing downward at brace | 7 | 66.4 | -4.1 | +0.2 |
| 3 | " | 7¼ | 66.2 | -1.2 | 0.0 |
| 9 | Mechanical ref., air delivered at doorway | 8¼ | 50.0 | -4.9 | -2.0 |
| 20 | " | 11 | 34.9 | -6.9 | -3.7 |
| 17 | " | 11½ | 36.5 | -3.1 | -1.3 |
| 6 | " | 12½ | 36.5 | -3.8 | -2.4 |
| 19 | " | 26-3/4 | 31.9 | -8.1 | -1.5 |
| 18 | Car equipment under floor racks | 14 | 40.6 | -2.1 | -1.7 |
| 8 | " | 18¼ | 48.9 | -0.3 | -1.1 |

1/ Average of temperatures taken in crates in top, middle, and bottom layers of bunker, quarter length and doorway stacks along center line of car.

2/ Crates in the top layer, bunker, quarter length and doorway stacks and middle, bottom layer, doorway.

FIGURE 1. COMPARISON OF FINAL PRECOOLING TEMPERATURES AND AVERAGE TRANSIT TEMPERATURES.

(TEST CAR INDICATED BY NUMBER ON CHART)

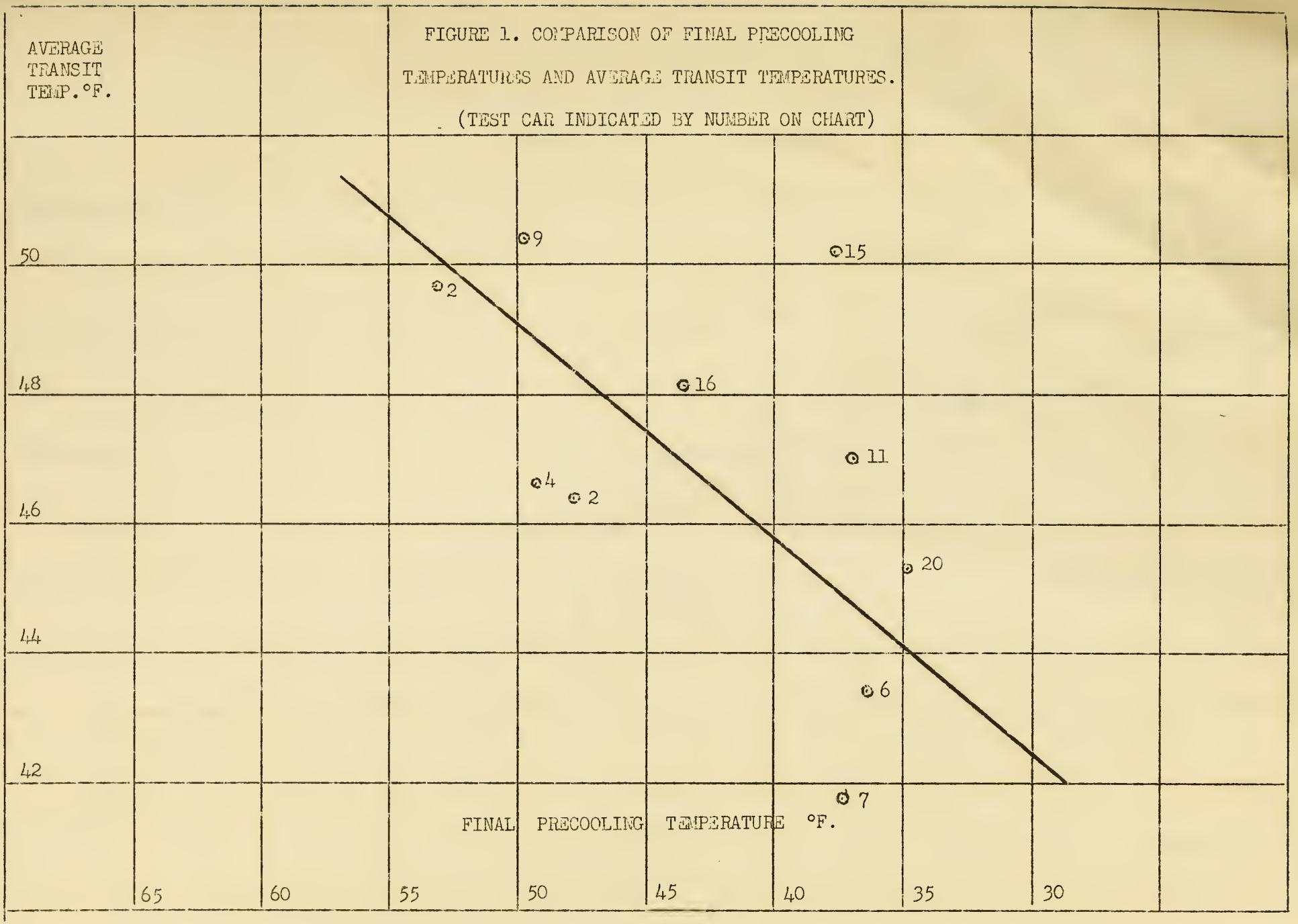
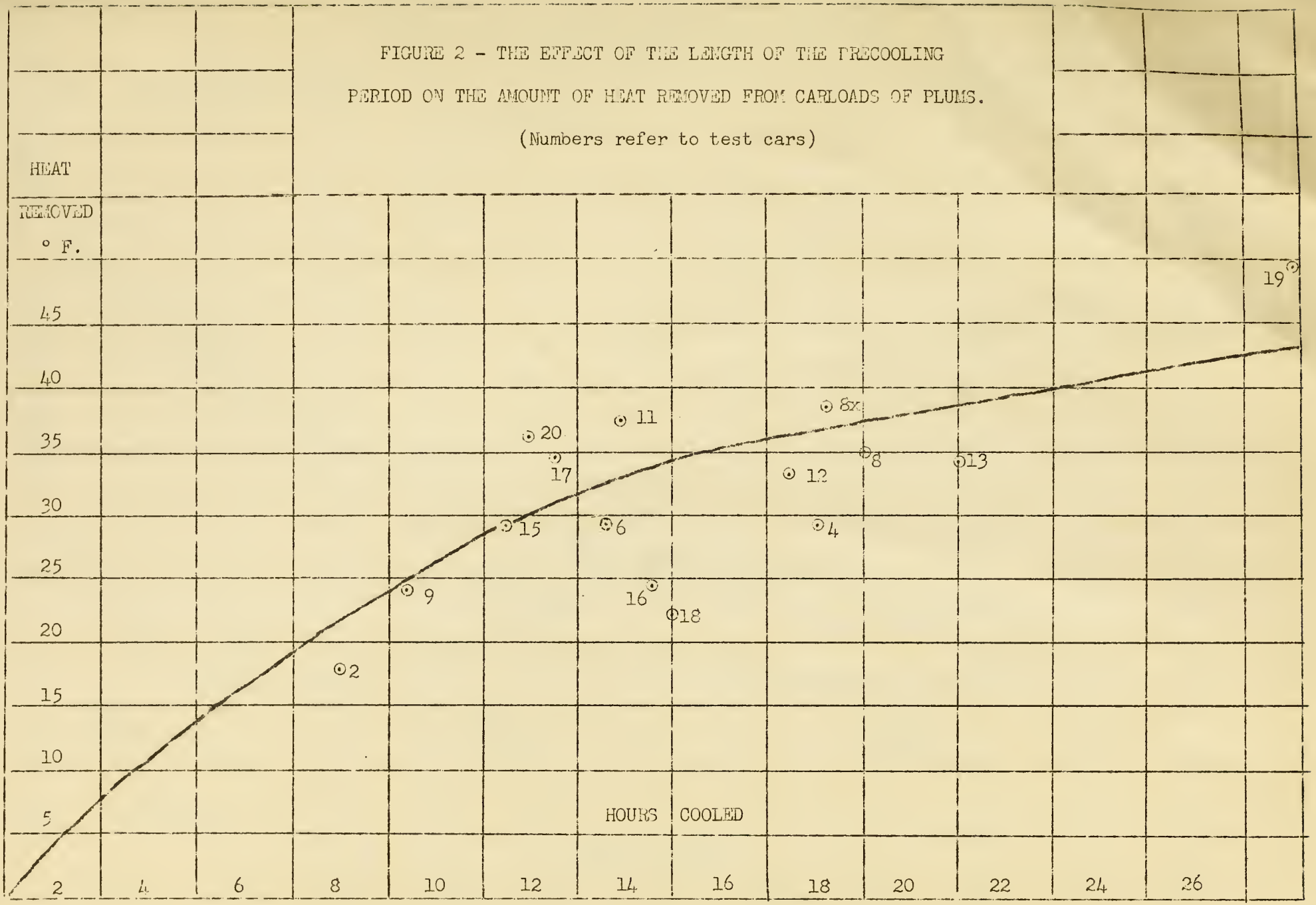


FIGURE 2 - THE EFFECT OF THE LENGTH OF THE PRECOOLING PERIOD ON THE AMOUNT OF HEAT REMOVED FROM CARLOADS OF PLUMS.

(Numbers refer to test cars)



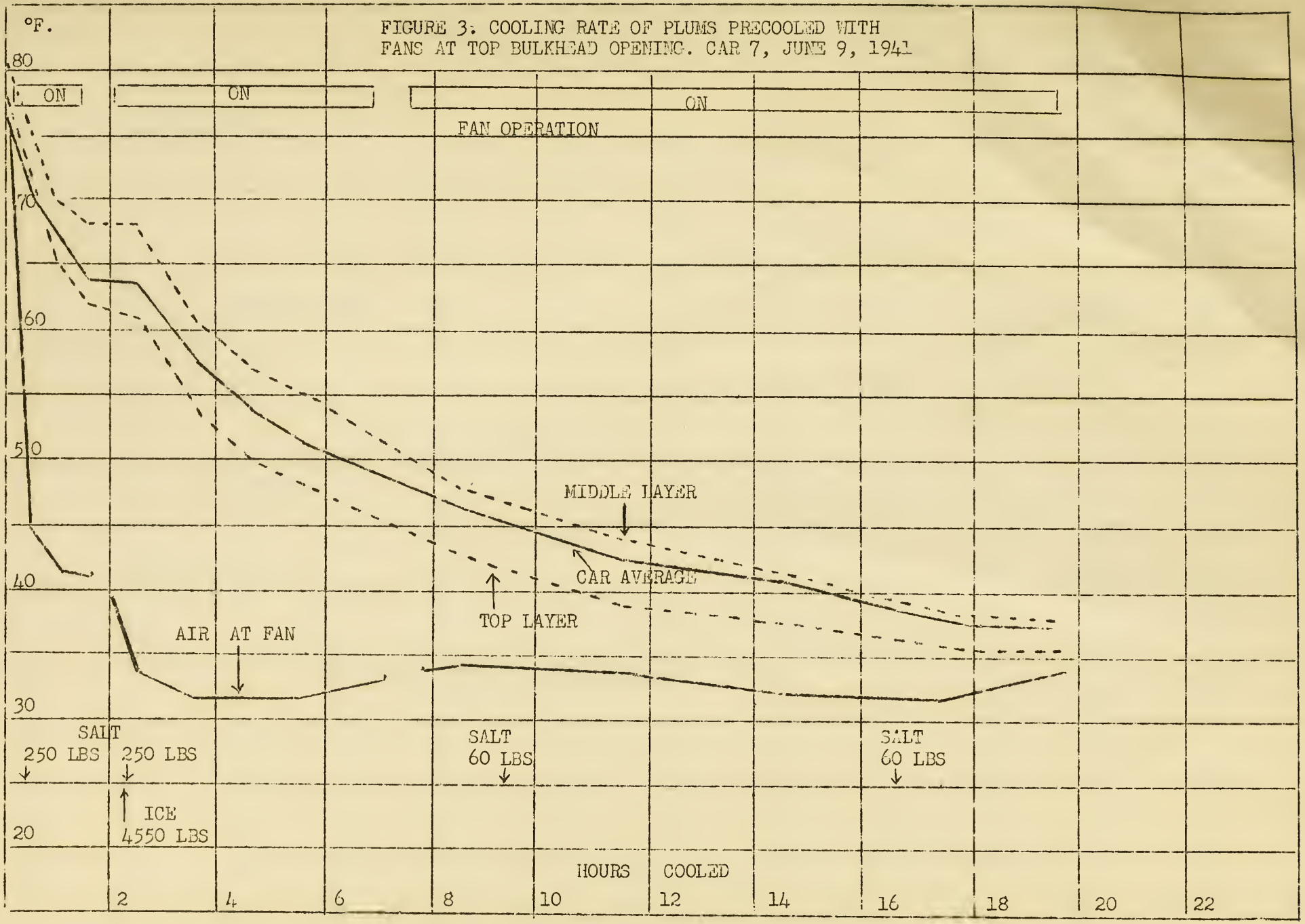



FIGURE 3. COOLING RATE OF PLUMS PRECOOLED WITH FANS AT TOP BULKHEAD OPENING. CAR 7, JUNE 9, 1941

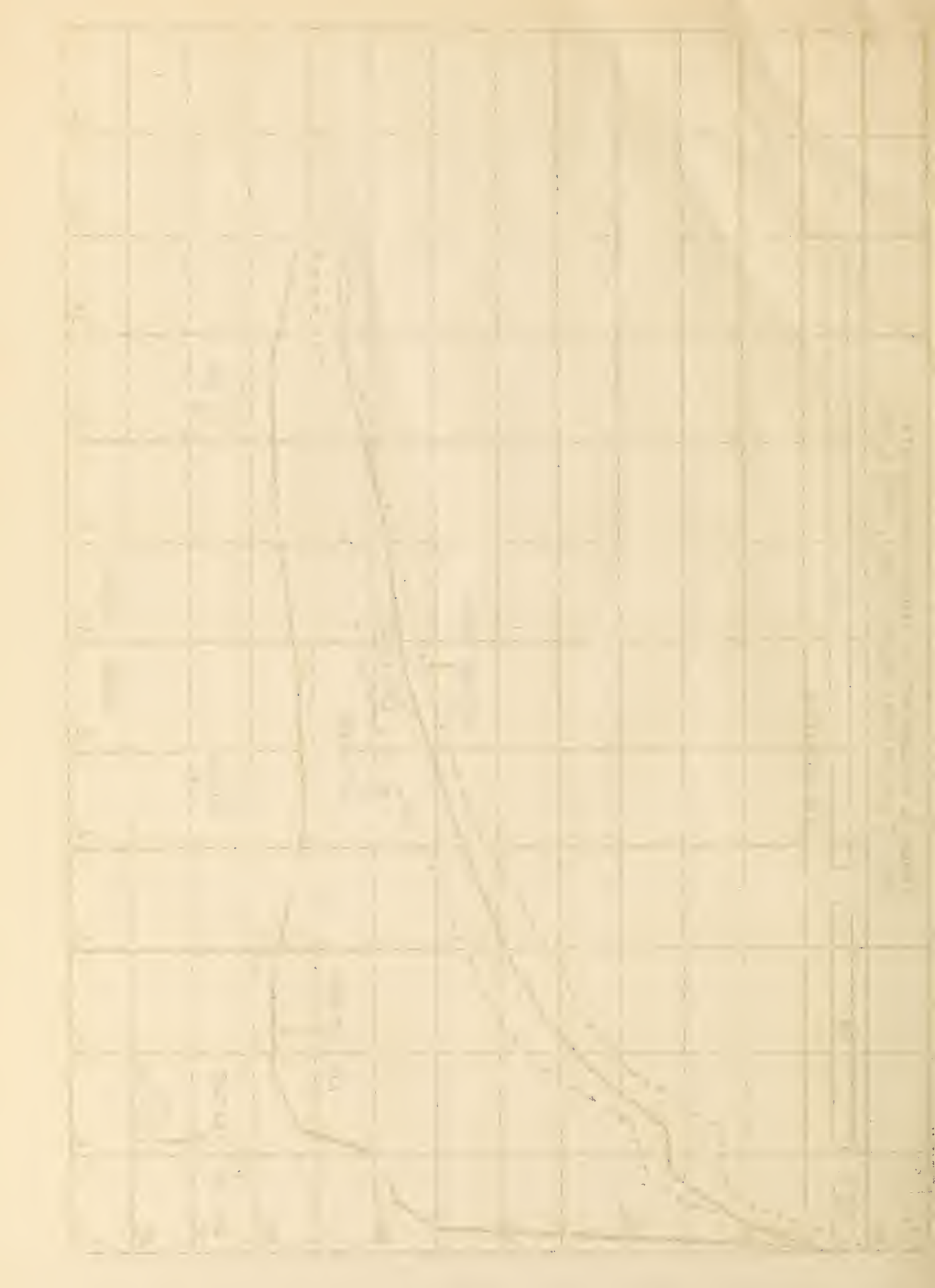
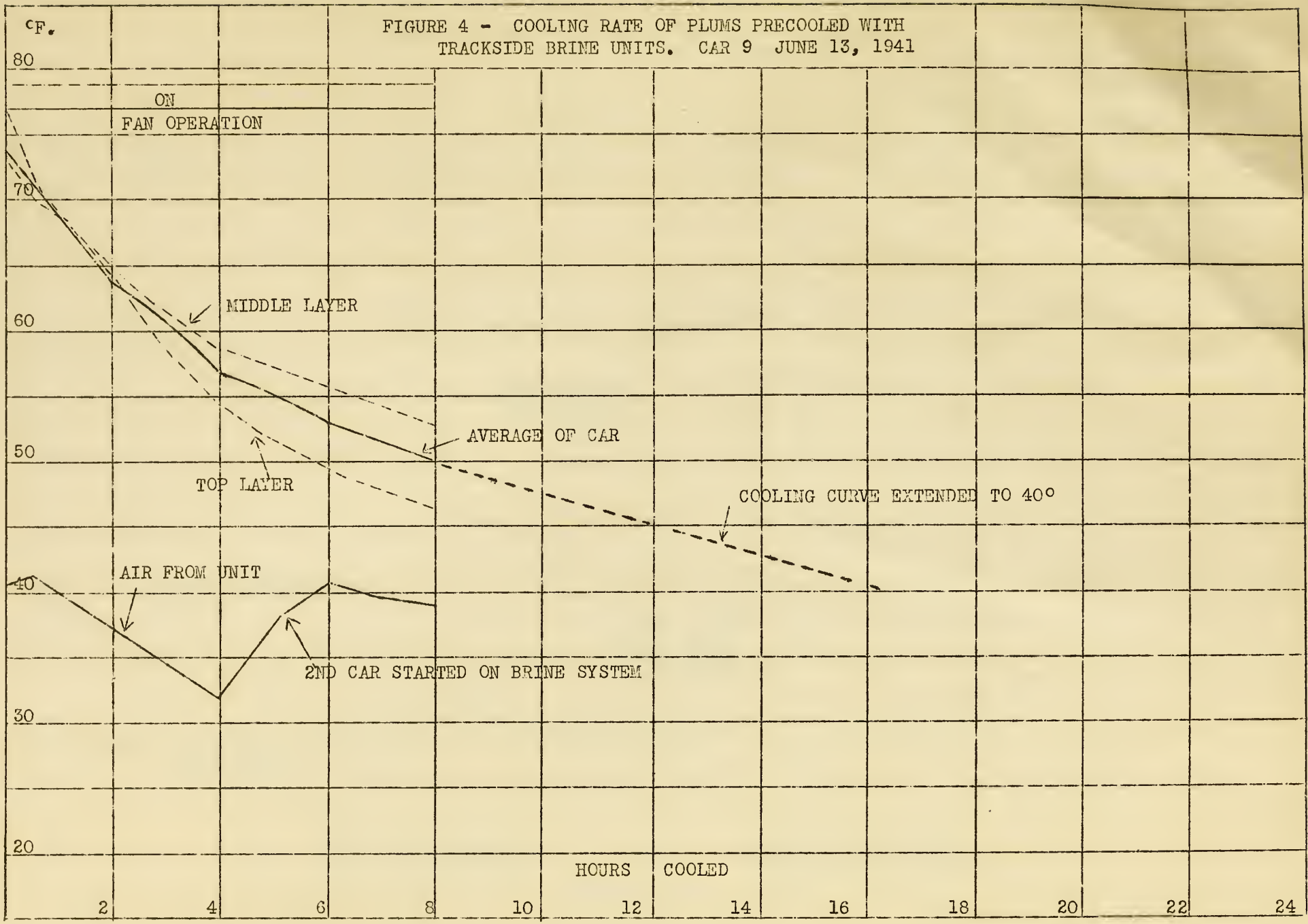


FIGURE 4 - COOLING RATE OF PLUMS PRECOOLED WITH TRACKSIDE BRINE UNITS. CAR 9 JUNE 13, 1941



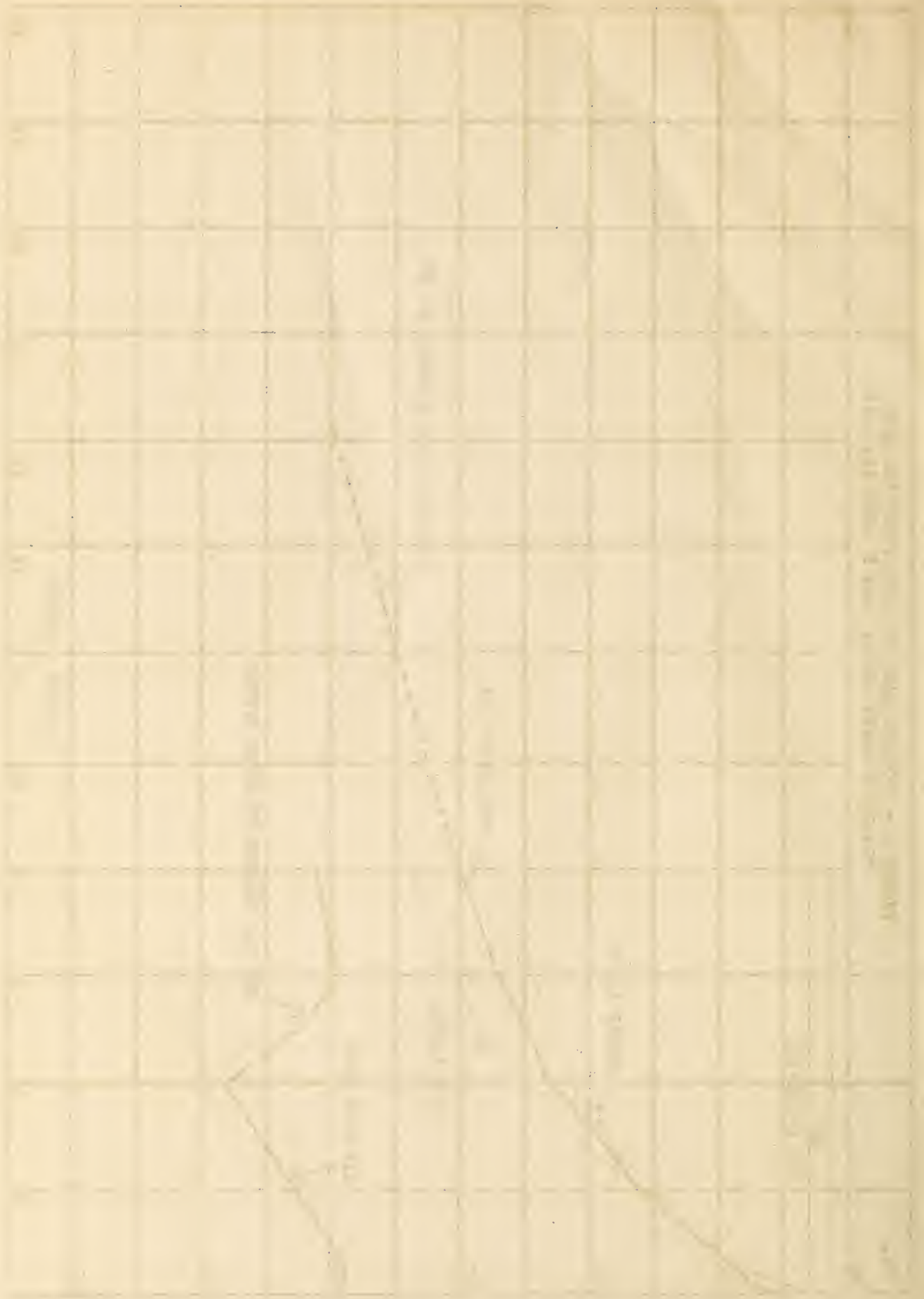
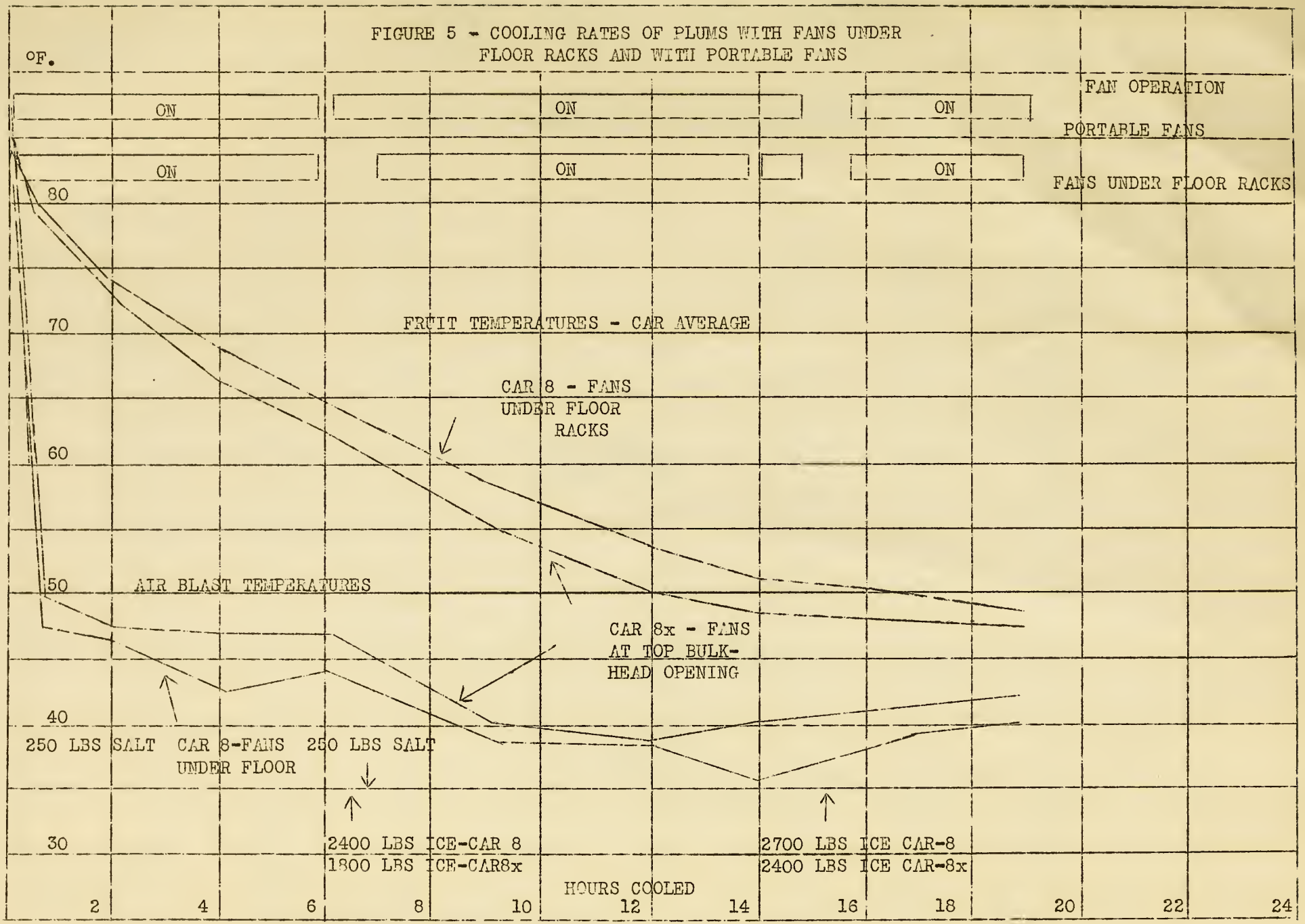
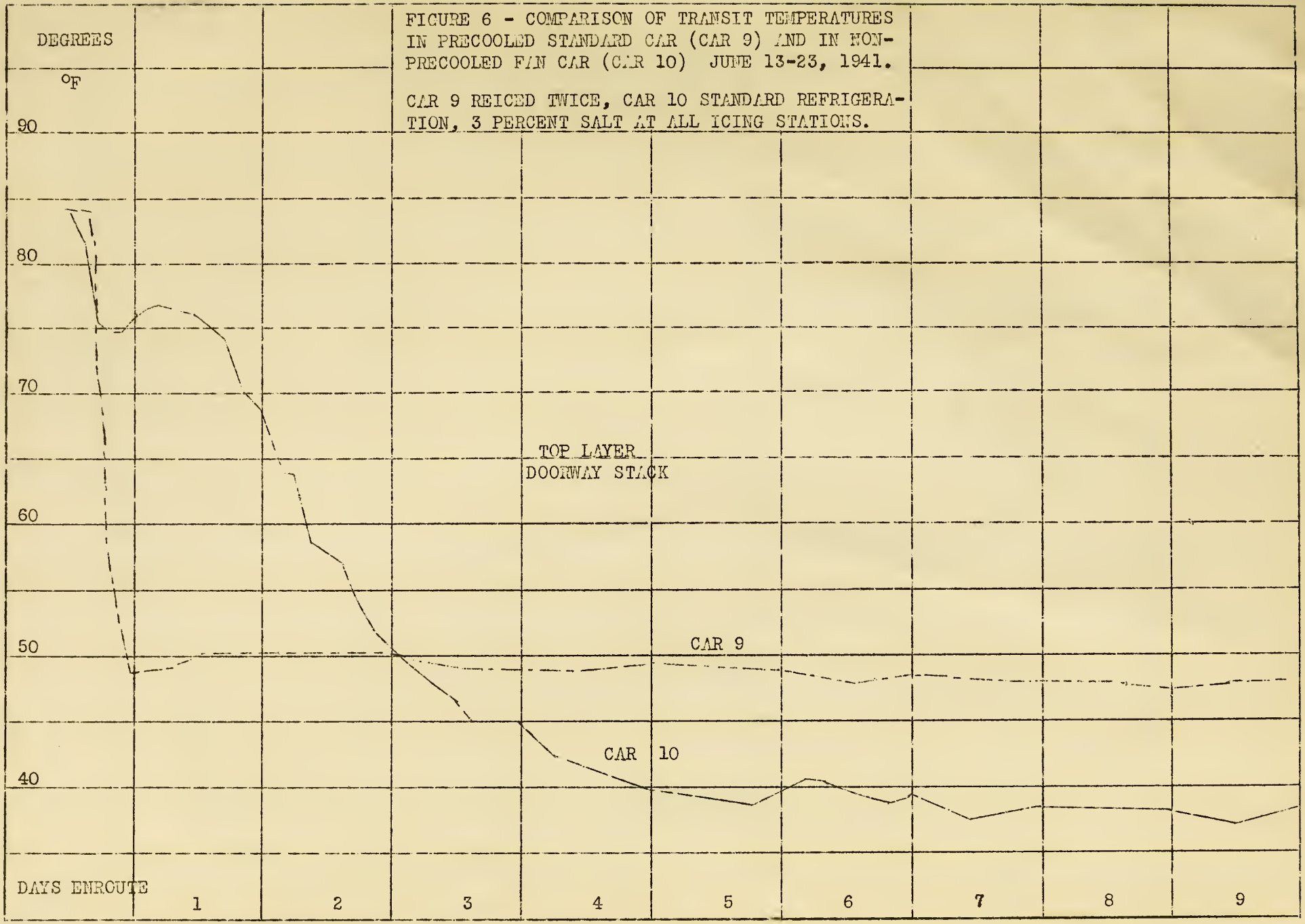


FIGURE 5 - COOLING RATES OF PLUMS WITH FANS UNDER FLOOR RACKS AND WITH PORTABLE FANS



FICURE 6 - COMPARISON OF TRANSIT TEMPERATURES IN PRECOOLED STANDARD CAR (CAR 9) AND IN NON-PRECOOLED FAN CAR (CAR 10) JUNE 13-23, 1941.

CAR 9 REICED TWICE, CAR 10 STANDARD REFRIGERATION, 3 PERCENT SALT AT ALL ICING STATIONS.



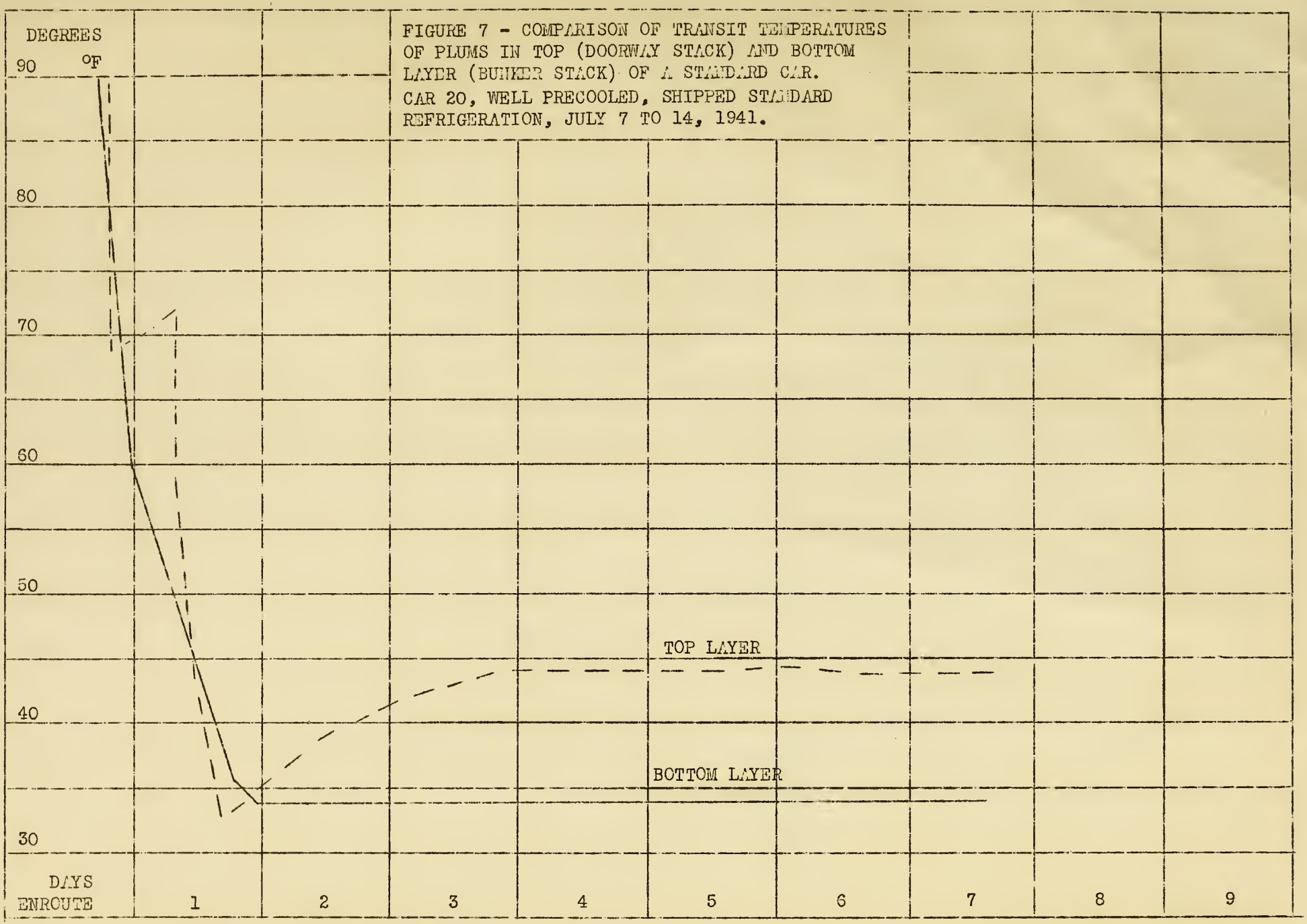



FIGURE 7 - COMPARISON OF TRANSIT TEMPERATURES OF PLUMS IN TOP (DOORWAY STACK) AND BOTTOM LAYER (BUNKER STACK) OF A STANDARD CAR. CAR 20, WELL PRECOOLED, SHIPPED STANDARD REFRIGERATION, JULY 7 TO 14, 1941.

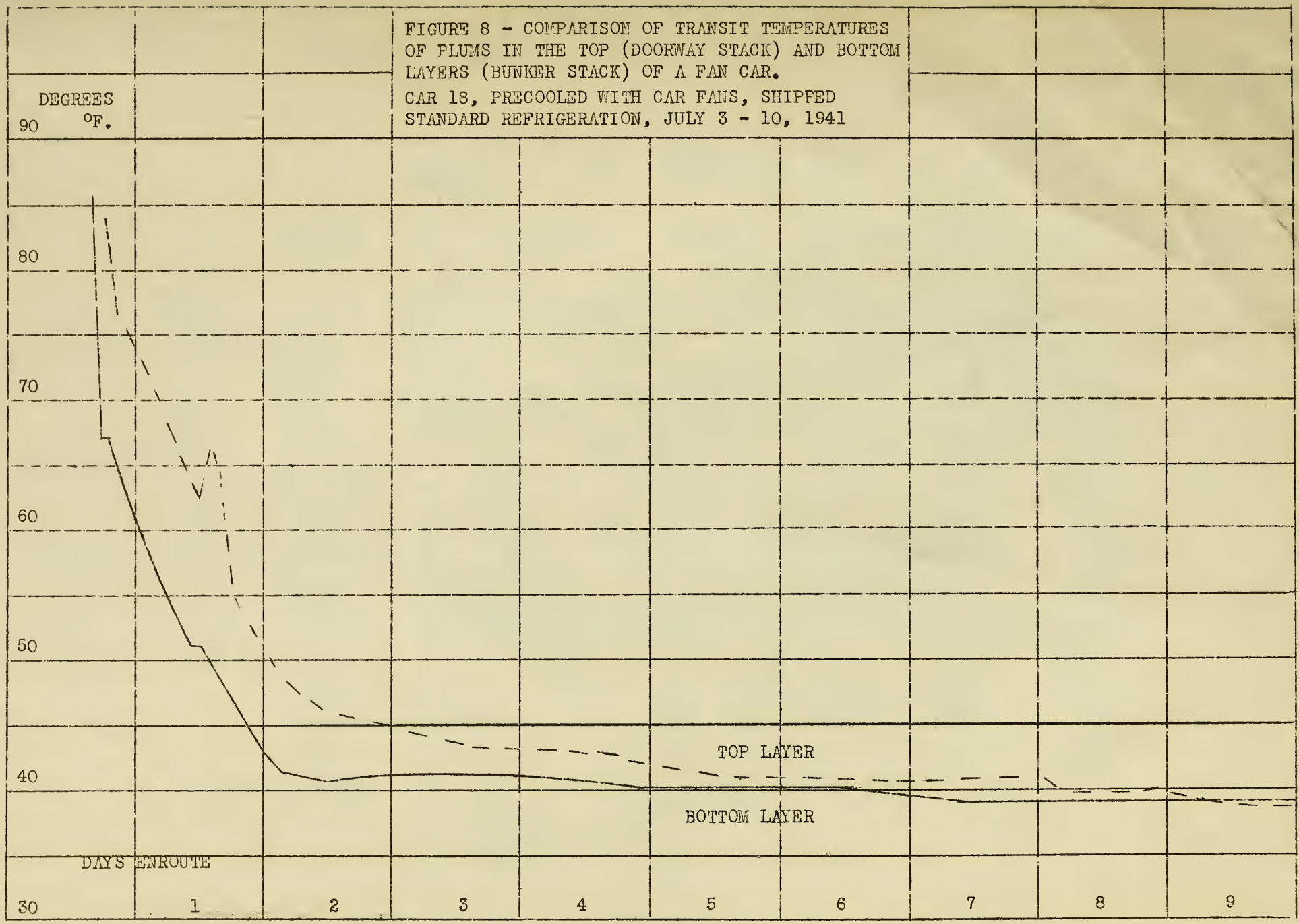



FIGURE 8 - COMPARISON OF TRANSIT TEMPERATURES OF PLUMS IN THE TOP (DOORWAY STACK) AND BOTTOM LAYERS (BUNKER STACK) OF A FAN CAR.
CAR 18, PRECOOLED WITH CAR FANS, SHIPPED STANDARD REFRIGERATION, JULY 3 - 10, 1941